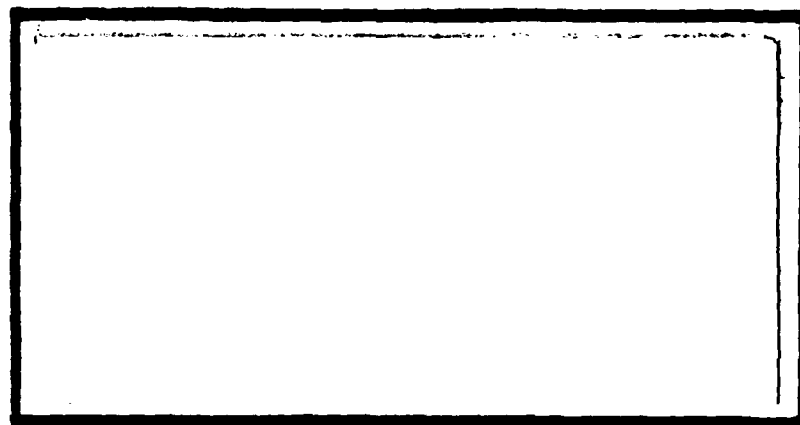


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EXPERIMENTAL INSIGHTS INTO THE  
MANAGEMENT OF RISK-RELATED BEHAVIOR

THESIS

Edward Skibinski  
Captain, USAF

AFIT/GLM/LSM/88S-68

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The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

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EXPERIMENTAL INSIGHTS INTO THE MANAGEMENT  
OF RISK-RELATED BEHAVIOR

THESIS

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Logistics Management

Edward Skibinski

Captain, USAF

September 1988

Approved for public release; distribution unlimited

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Abstract

Research has shown that people respond in varying ways to decisions involving risk. This is of particular interest in the field of logistics. The purpose of this study was to determine whether organizational policies which address risk can produce a significant and predictable influence on risk-related logistics decisions. An experiment was conducted using 117 logistics managers and graduate logistics students. Three policies which specifically addressed the elements of risk were tested for a significant influence on a logistics decision which was based on cost and reliability factors.

Analysis of the responses to the experiment showed that risk significantly affected the logistics decision. Further, the research showed risk-inherent decisions can be purposely influenced by policies which address risk. However, a significant five-way interaction between the policy variable and the other decision variables demonstrated the enormous complexities involved in logistics decision making. No absolute generalizations could be made about any risk policy; the policies produced a significant difference only in certain situations involving certain variables.

A policy which allowed for no uncertainty in the decision outcome (thereby eliminating risk) was most consistently and universally applied. This policy was easily understood, easy to follow, and generally adhered to. A policy which allowed for no negative outcomes (also eliminating risk) was applied only to those variables deemed important by the decision makers, promoting risk-seeking actions in these cases. Finally, a policy which allowed for small risks and focused attention on risk, but in vague and indiscriminate terms, was also not universally applied to all decision variables. Consequently, organizations may not achieve the desired results from such a policy. Whether such policies are appropriate for logistics organizations would depend on those particular organizations.

This research suggested that managers recognize the variables in which risk is manifested in their organizational decision making and examine the intricate roles risk plays. Now that it has been shown that policies do make a difference, managers should initiate a systematic study to determine which policies influence the decisions in their particular organizations. Finally, policies which address risk should be established which account for the complex interactions between decision variables and perpetuate the goals of those organizations.

## EXPERIMENTAL INSIGHTS INTO THE MANAGEMENT OF RISK-RELATED BEHAVIOR

### I. Introduction

#### General Issue

A growing body of research shows that decisions people make are greatly influenced by the perceived risk and uncertainty inherent in the decision outcomes. This general theme has spawned further interest in several corollary disciplines. Research efforts into the value of utility theories, risk assessment processes, and risk management attempt to substantiate the role risk plays in decisions involving alternative outcomes.

While it is widely recognized that risk plays a vital role in decision making, very little is known concerning whether organizations can affect how managers consider risk and uncertainty in their decision making. Managers make countless decisions daily in an effort to perpetuate organizational goals; are they, in fact, influenced by organizational policies when making decisions in the face of uncertainty?

The effects of uncertainty and risk on the decisions managers make and the influence of organizational policies or guidance should be of central concern in the field of logistics. This is particularly true in the military.

Military logistics must inherently address many risk-related issues. For example, base inventory policies and the composition of war readiness spares kits (WRSK) used by the Air Force are explicitly based on risk assessments (50). The ability to support peacetime or combat operations becomes a function of the risks involved in predetermining base supply stockage levels and choosing the supplies to be included in organizations' WRSK. The choice between preventive maintenance or "fly until failure" maintenance policies is another example of how the Air Force reacts to risk-related concerns. In fact, the responsiveness of the Air Force logistics support structure is a function, in part, of how its policies address risk.

Recently, both business and military logistics have received increased scrutiny (44:72-79; 19:23-34; 29). Organizations have found that information regarding many areas of logistics is sometimes vague or uncertain. Delivery schedules, manning levels, and expected reliability rates are examples of logistics concerns that are often tenuous. Basing decisions on uncertain information is thus inherently risky and could have profound negative consequences. An organization's ability to either predict or influence how its managers will approach risk-related logistics decision making may be fundamental to the success of the organization.

## Background

Risk-related decisions play integral roles in the success of many military, business, and personal ventures. Decisions made between alternative choices, one or more of which have the chance of resulting in a loss (hence, risk), are common at every level of human decision making. Logic dictates that decisions should be based on maximizing the expected utility from the decisions and that this decision process should necessarily follow some form of mathematical rationality. However, research has shown that this is often not the case; repeated and consistent violations of mathematical rationality occur in all types of decisions (34:801; 17:664; 37:6-7).

Inconsistencies in human rationality have motivated researchers to better explain how decisions are made under conditions of uncertainty. Information used in decision making is frequently clouded in uncertainty. Often, assumptions must be made due to time or information constraints. This leads to subjective assessments of both potential decision outcomes and the probabilities associated with these outcomes. Seldom will two people agree exactly on these assessments and neither of their perceptions will necessarily reflect reality. Dissimilar decision choices therefore often result from these ambiguities of perception (52:38-53).

Even when outcomes and probabilities can be stated as factual, subjectivity again plays a major role in a

decision (36:116). Some people tend to focus on the outcomes (irrespective of the probabilities of occurrences) and will weight them in a non-linear manner. Similarly, some decision makers focus on the probabilities and, for example, may weight a 50% chance of an event as more than twice as valuable as a 25% chance of occurrence. This concept is the basis of many proposed utility theories which are modified by an element representing a decision maker's subjectiveness. Kahneman and Tversky's prospect theory is an example of a utility theory which uses an elaborate non-linear weighting scheme (30:454).

Risk assessment plays a crucial role in the field of logistics (18). Information concerning logistics functions is sometimes available only in uncertain, speculative, or unreliable terms. Decision processes, therefore, must include an evaluation of the risks involved. While many logistics decisions are repetitive in nature, logistics managers frequently must address decisions concerning one-time occurrences. In these cases they seldom have the luxury of basing decisions on historical precedence. The source selection process for a new weapon system, for instance, is a large scale one-time logistics consideration that can only be indirectly guided by past source selection decisions. The possible consequences due to poor decision choices further highlight the role that risk plays in logistics decision making. Very little research has investigated whether the risk-related decisions these



managers make are influenced by the goals and policies of the organization for whom they are employed.

Chapter II of this thesis contains a more comprehensive literature review of these areas.

### Problem Statement

Employees at every organizational level are confronted with decision alternatives that involve risk and uncertainty. Previous research has shown that people address these decisions in a variety of ways. Due to the uncertain nature of logistics decision making and the potentially negative consequences of poor decisions, knowledge of how logisticians react to risk is profoundly important. Certain management policies which focus on the basic elements of risk may influence the effects of risk on decisions made by logisticians. It is not known, however, which management actions or policies, if any, produce a more predictable influence from risk and uncertainty on decision choices made by managers.

### Research Objectives

The overall objective of this thesis was to determine whether management policies can influence how logistics managers make decisions involving risk and uncertainty. The following research questions were raised:

1. Can an organization establish policies addressing risk that change the way managers assess risk-inherent decisions?
2. Do the presence of risk and uncertainty affect the way logistics managers make decisions?
3. Do significant interactions exist between various levels of cost, cost certainty, reliability, reliability certainty, and risk policies when making decisions concerning logistics issues?

#### Justification

Risk assessment is unavoidable; people are continually making decisions involving risk-related factors that they assess and analyze either consciously or subconsciously. Those decisions often are fundamentally important both to individual decision makers and to their employers. "Choice in the face of risk involves an important class of individual and societal decisions" (43:1). A better understanding of how we perceive risk and whether our risk perception can be purposely influenced should be of primary interest to managers close to the decision making process. This is especially true of the military which operates in an environment of risk.

Managers in the field of military logistics devote the majority of their time addressing risk-intense decisions. Arguably, the military has the most profuse logistics system in existence. A major portion of DoD's approximately \$300 billion budget is appropriated to programs which strive to maintain an acceptable level of logistics support (8:112). The consequences of insufficient training for maintenance personnel, the inability to retrieve parts from the supply pipeline, or failing to provide accurate technical data documentation could result in lost aircraft sorties or, worse yet, lost lives. At the very least, the inefficiencies from poor logistics decision making could result in wasting millions of dollars. A heightened awareness of the influence of risk and uncertainty on logistics decisions is, therefore, profoundly important (18:131).

Recent events in the Persian Gulf give some indication that management may be able to influence risk-related decisions. The captain of the USS VINCENNES was instructed to be on heightened alert for a possible Iranian air attack on his cruiser around the July 4th 1988 time frame. On 3 July, he and his crew mistook an Iranian airliner for a hostile military plane and, after issuing four warnings, tragically, shot down the aircraft (54:16-24). Had his guiding instructions instead explicitly been, for example, not to fire unless he was absolutely sure it was a hostile aircraft, his decision

presumably would have been different. It would certainly be useful to know whether alternate guidance with respect to risk would change the decision choices people make. This thesis begins to examine whether certain policies can affect the way risk is considered in logistics decision making.

### Scope

The scope of the experiment used to meet the objective of this thesis involved testing logistics managers, logistics specialists, and logistics students in a hypothetical acquisition setting. In that setting, an organization wished to purchase an advanced computer system. The test subjects were asked to evaluate 16 different proposals based on cost and reliability factors. They were each asked to rate the 16 proposal alternatives on an interval scale from one to one hundred.

The cost and reliability in each proposal were expressed either in certain terms or terms of uncertainty. The expected values associated with the uncertain alternatives were either positive (a savings compared to the budget or a relative improvement in reliability) or negative (more costly than the budget amount or a less reliable system). Regardless of the expected value, each uncertain element of the task contained some possibility for a relative loss, thereby introducing risk into the choice.

The risk involved in the cost factor differed from than the risk involved in the reliability factor. The test

subjects were given a budget of \$100,000. Costs incurred above this amount would negatively impact the funds available to their organization for training or the purchases of other items. Exceeding the budget was therefore presented as a "loss". The proposed reliability rates were compared to an industry standard of 90 percent. Accepting a system with a reliability less than the industry norm represented a loss in terms of reliability compared to the average of all the systems on the market.

The participants in the thesis experiment were divided into four test groups. Three groups were each presented with a different policy addressing risk. Policy A specifically addressed risk and desired no uncertainty. Policy B focused on consequences. Management wanted no alternative where the system's cost or reliability could result in a loss. Policy C focused on probabilities. By allowing for a "small chance" of a loss, the logistics managers needed to specifically address those alternatives in which a loss was a possibility. These would be viewed differently than those alternatives where a loss was certain or where no chance of a loss existed. Finally, Policy D offered no guidance and the test subjects in this group represented the control group. Table 1 shows the exact wording of the guidance for each policy.

---

Table 1. Organizational Policies

<u>Policy</u>	<u>Guidance</u>
A -	[Your supervisor] is adamant that both cost and reliability data be known absolutely before awarding the contract. If these factors are known beforehand with 100% certainty, even though they may be unfavorable, he can immediately plan other courses of action based on those figures.
B -	[Your supervisor] reminds you that recent acquisitions have resulted in overbudgeted purchases for equipment that have failed to meet reliability specifications. He has stated that he does not want to purchase any system that will cost greater than \$100,000 or perform at less than a 90% reliability rate.
C -	[Your supervisor] is interested in awarding the contract to the most deserving proposal. It is desirable that the system perform with at least a 90% reliability rate and cost less than \$100,000, but your supervisor is willing to accept a proposal with a small chance of not meeting these criteria.
D -	(No guidance was given)

---

Table 2 includes two sample alternatives. Both are equal in terms of expected values; however, risk and uncertainty are included only in alternative # 2, and this proposal may be viewed as more or less appealing than the first alternative. There are sixteen possible proposal alternatives combining certainty and uncertainty with positive and negative expected values. Each test subject within each test group evaluated each combination. Additional details of the experimental design are discussed

---

Table 2. Example Proposal Alternatives

Proposal Alternative # 1:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: 90%):

100% chance the system will be up 93% of the time

I rate this alternative as: (1-100)

-----

Proposal Alternative # 2:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000

30% chance of costing \$ 90,000

20% chance of costing \$105,000

10% chance of costing \$120,000

System reliability is expected to be (Industry average: 90%):

40% chance the system will be up 98% of the time

30% chance the system will be up 94% of the time

20% chance the system will be up 87% of the time

10% chance the system will be up 82% of the time

I rate this alternative as: (1-100)

---

in Chapter III. Appendices A-C include the entire thesis experiment.

#### Assumptions and Limitations

Foremost among the assumptions is that responses in rating the alternatives were accurate and representative of actions that would follow. Artificial experiments have this inherent limitation. In the experiment, the logisticians realized the money was imaginary and may have been more apt to view risk in a less threatening perspective as a consequence (36:121). Since the thesis instead concentrated on influencing risk-related decisions, this limitation applied to each group and was, therefore, a less significant factor.

The choice of probability distributions and dollar amounts can be viewed as a limitation to the experiment. For example, a \$20,000 loss represents varying degrees of severity among individuals. Also, incremental dollar figures are perceived as unequal (53:454). For instance, a 1,000 dollar change of costs from \$1,000 to \$2,000 is typically more significant than from \$60,000 to \$61,000. The choice of dollar figures could influence risk assessment. The experiment used similar numbers expressed in intervals of easily manipulated dollar figures. The intent of the experiment was not to turn the decision choices into an exercise in mathematics; however, if the logisticians chose to compute expected values the



mathematics were relatively simple. The consequences of both of these potential limitations were minimized by the random assignment to the groups. Group equivalence was assumed for the participants view of monetary values and for their mathematical abilities.

All of the test subjects were DoD personnel. Their backgrounds may have influenced the manner in which they perceived risk. There may be an inability to use the conclusions in this thesis to generalize to managers in other fields working for other organizations. The experiment used both logistics managers, logistics specialists, and logistics students. These people all understand the basic tenets of logistics; however, not all of the students had field experience in a logistics capacity. Comparisons between the students and managers would determine if any significant differences exist. In addition, assigning a similar number of students to each test group would also limit the problem.

The experiment's perceived realism may be a limitation on the research. If any of the subjects had purchased computer systems and based their decisions, instead, on additional organizational criteria, their evaluations may have been affected. Further, subjects involved in purchasing of any type may feel that nothing in the acquisition arena can be stated with 100 percent certainty. The experiment accounted for this by twice repeating management's firm belief that the data were accurate and

that all decisions should be based on the data presented. As before, the random assignment to groups should also have limited any impact on the research conclusions.

Finally, there is the chance that the organizational guidance presented in the experiment's introduction was overlooked or misunderstood. To avoid this, the guidance was underlined in the introduction, then restated before the evaluations were made. Also, the questionnaire that followed the experiment asked for the respondents to restate their supervisor's guidance about cost and reliability uncertainty in their own words. The test subjects' comprehension of the policies can thus be examined. Further, pretesting the experiment identified the few ambiguities which were present in the initial product.

### Research Organization

This chapter introduced the general topic of this thesis research including an overview of risk and its prevalence in logistics decisions. It introduced the concepts behind the experiment used in the research to measure the influence of organizational risk policies on the way managers consider risks in decision making. Chapter II presents a literature review on risk, decision making under conditions of uncertainty, and risk-related issues in the military and the field of logistics. Chapter III is a more thorough examination of the research methodology. Chapter IV includes an analysis of the data from the experiment.

Chapter V concludes with the major findings and pertinent recommendations.

## II. Literature Review

Review of the pertinent literature reveals that both theoretical and empirical research have primarily focused on how decisions are made under conditions of uncertainty and on risk-taking propensities of individuals. Scholars have had only moderate success in marrying the concept of individual risk-taking propensities with classical decision theory to gain better insights into human decision processes. Research on this topic has generally attempted to explain the reasoning behind the decisions people make when confronted with risky decisions..

### Risk

In nearly every field of human endeavor, man is faced with decisions involving risk. Not only are risks unavoidable, but they are often desirable in order to enhance our lives or provide excitement (36:5). Risk-taking decisions are routinely made on financial, social, legal, political, and personal issues. In fact, the foundations for many issues in economic theory and psychology theory are firmly rooted in risk analysis. In recognizing risk's pervasive nature, Moore conveys three principle messages: first, risk arises in virtually all fields of endeavor; second, it is important not to be frightened by risk nor to ignore it; and, third, it is possible to assess and handle risk with systematic methods (38:ix).

Unfortunately, there is not a widespread consensus on the basic definition of risk. Perhaps the first commonly used meaning of risk was advanced by Knight. He distinguished the concept of risk in decision making from that of uncertainty. Risk was involved in a decision if the chance of an outcome could be stated with a known and measurable probability distribution. Uncertainty, on the other hand, involved decisions where the probabilities associated with the outcomes were unmeasurable or could only be speculated (32:20). The toss of a fair coin, therefore, was risky but not uncertain; whereas, tomorrow's weather would be considered uncertain.

More recent research efforts, such as those done by MacCrimmon and Wehrung (36), Emmelhainz (19), and Borch (5), have viewed risk and uncertainty in a different light. The outcome of a decision is uncertain unless it can be predicted with 100% assurance. If a decision could yield two or more possible outcomes, it is uncertain. Risk, as MacCrimmon and Wehrung explained, is inherent in any decision where the outcome is uncertain and there is a potential for a loss (36:9). Uncertainty then is a necessary but insufficient condition for risk. Unless a chance of a loss is one potential outcome, risk is not present. At the same time, if an outcome is a sure loss, there is again no risk involved. This view is not concerned with whether the probabilities are known or are subjective as Knight had insisted; precise probability becomes

immaterial. In fact, Cohen and Hansel viewed risk as subjective probability in action (7:4), a notion Knight would likely have disagreed with.

MacCrimmon and Wehrung also identified two types of losses. One type is an outcome that is worse than if no decision were made, or the status quo. The other type is an opportunity loss where one outcome is not as good as another outcome that might have been obtained. This type can be treated as a loss when decision outcomes are presented in comparable forms (36:10). Thus, if A is worse than B, A then represents a loss.

This thesis treated risk as MacCrimmon and Wehrung did. Such treatment is consistent with the definition provided by Webster's New World Dictionary: "risk:...the chance of injury, damage, or loss [emphasis added]" (55:1228). Uncertainty, on the other hand, was viewed as the lack of sureness concerning an outcome. Outcomes which could only be stated in probabilistic terms were considered uncertain.

#### Decision Making Under Conditions of Risk

Very often decision making under conditions of risk involves an attempt by the decision maker to maximize the resulting utility of the decision.

The case of decision making under risk is one in which considerable consensus exists among decision experts as to how one ought to choose. The theory advises which alternative to select in complex decision situations on the basis of one's basic taste or preferences about risk and the intrinsic value of the attribute(s) under consideration. Both of these elements are captured through a utility function so that maximizing expected utility becomes the guide to rational behavior in more complex situations [43:11].

The key point is that people ought to make choices based on a probability of outcome coupled with the perceived expected utility of that outcome. Rational behavior dictates that the highest expected utility would render the logical decision choice.

Schoemaker wrote that this concept of the rational man can be traced as far back as the writings of Greek philosophers, and that the idea of a rational-economic man played an important role in early economic theory (43:2). That decisions would be based on sound deliberation and reasoning, instead of habit or emotion, is fundamental in all classical utility function theories.

However, it has been shown that people do not make decisions based solely on expected utility. Consistent and repeated violations of rationality occur and these violations are neither random nor small-scale (34:806).

Conceptually, the subjective expected utility model is a beautiful object deserving a prominent place in Plato's heaven of ideas. But vast difficulties make it impossible to employ it in any literal way in making actual human decisions [46:100].

For example, Edwards and Von Winterfeldt cited studies where subjects were asked to choose between lottery A (a high

probability of winning a medium amount of money) and lottery B (a low probability of winning a large amount of money). Most chose lottery A. However, when asked to bid for these lotteries, they were willing to bid more money for lottery B than lottery A (17:664). Such occurrences of "preference reversals" are logically irrational, yet very common.

Other examples of violations of the postulates of utility theory are profuse in the literature. MacCrimmon presented 38 subjects with the six possible binary combinations of four risk-taking alternatives: A, B, C, and D. The subjects were asked which alternative in each pair they preferred. The subjects were then asked to rank the four alternatives from one to four in order of preference. Two of the 38 subjects had "intransivities" where, for example, A was chosen over B, and B was chosen over C, but C was then chosen over A. This is also known as a circular triple. Eighteen of the subjects had a discrepancy between their binary choices and the overall rankings, therefore demonstrating "choice instabilities" (37:6-7).

Clearly, expected utility alone is insufficient to explain decision choices in risk-related decisions. Risk affects decision making such that choices which will yield the highest expected utility in the long term are often not made. Perhaps because most decisions are made for the short term involving one time decisions, expected utility is often violated. The fact that a certain course of action will yield favorable results 70% of the time in repeated



situations may be inconsequential to a decision maker who must make that decision only once. It will either be favorable or unfavorable, and a 30 percent chance of an unfavorable outcome may be too risky for his particular situation (38:8). Decision makers, therefore, may tend to focus primarily on the probabilities or on the magnitude of outcomes in making their decision choices. This may come at the expense of "mathematically rational" decision theory.

Other explanations have been given for human irrationality (commonly referred to as "bounded rationality") when confronted with risk-related decisions. Tversky and Kahneman have shown that the framing of a situation will affect the decision choice (53:453). In one experiment, they asked 152 people to imagine the U.S. was about to experience an outbreak of an unusual disease which was expected to kill 600 people. The people could choose between two alternative programs. These were:

- "A. Program A where 200 people would be saved; or,
- B. Program B where there is a 1/3 chance all 600 people would be saved and a 2/3 probability that no one would be saved" (53:453).

The expected value of each program is identical but 72 percent of those tested chose the certain choice of Program A.

A second group of 155 people were given the same cover story with these two alternatives to choose from:

"C. Program C where 400 people will die; or,

D. Program D where there is a  $1/3$  probability that no one will die and a  $2/3$  probability that all 600 will die" (53:453).

Again C and D have identical expected values and, in fact, C is just another way of wording A in the previous choice, as D is just a rewording of B. However, this time 78 percent of the subjects chose the risky alternative D. Simply by reframing the question, the alternatives were viewed in a different perspective, and a different choice was made.

Tversky and Kahneman believed that most people, experts and laymen alike, are generally misinformed about mathematical facts. These researchers have enumerated several ill-founded sources of biases that cause errors in the heuristics and intuition people use in making decisions (52:38-55). Among these common mistakes are insensitivities to prior probabilities, misconceptions of chance, illusions of validity, illusory correlation, anchoring, and biases in the evaluation of conjunctive and disjunctive events.

The fact that decisions are often made based on perceived outcomes (which are uncertain) may contribute to seemingly irrational decision choices. In most day-to-day decisions, both the probability of an outcome and the magnitude of an outcome are subjectively established and judged in the decision making process. Since human perceptions are frequently not in accord with reality, these

subjective judgments could lead to illogical action as perceived by another observer.

Mismatches between ecological validities and subjective utilization of cues are one source of inaccurate judgments. In other words, one source of poor judgment lies in the failure to attach the correct relative weights or importance to cues [23:8].

Schoemaker cited studies which attempt to generalize about subjective probabilities (43:31). Actual high probabilities are typically underestimated while low probabilities are overestimated. Further, subjective probabilities are often higher when the outcomes are more desirable (i.e., wishful thinking). Finally, Moore showed that most people believed their decisions were more certain than they actually proved to be. He asked approximately 100 questions of the participants, then asked for a probability of how "certain" they were of their answers. The individuals consistently believed themselves to be more certain than they, in fact, were (38:51).

In light of man's inherent bounded rationality, some researchers have proposed explanations for risk-related decision making. Kahneman and Tversky (30) proposed an elaborate, subjectively weighted utility theory that they called "prospect theory". Counter to classical theories where the utility function is linear, prospect theory uses a non-linear value function and a decision weight which modifies a monotonic probability function. Prospect theory, then, predicts that people will generally be risk averse when decision choices lead to positive outcomes. However,

people will react in a risk seeking fashion when outcomes involve losses. In an experiment involving 150 people, 84 percent chose a sure gain of \$240 over a combined 25% chance to gain \$1000 and a 75% chance to gain nothing. On the other hand, 87 percent of the participants preferred a 75% chance of losing \$1000 and 25% chance of losing nothing, compared with a sure loss of \$250 (53:454). Risk aversion predominated in gaining situations; whereas, risk seeking behavior was the preferred course of action in outcomes involving losses.

Looms and Sugden believed that risk-related decisions are explained better by regret theory. They proposed that the classical axioms of von Neumann-Morganstern's utility theory constitute an excessively restrictive definition of rational behavior. Instead, people more closely follow a complex and detailed utility function which is modified based on the regret or rejoicing of a decision between alternative choices. Decisions then are made to maximize this modified utility function. Regret theory purports to have normative implications based on an individual's capacity to anticipate feelings of regret and rejoicing (34:801-822).

Maximax gain, maximin gain, and minimax regret criteria (2:615-616; 38:207-208) are examples of other theories found throughout the decision making literature. Maximax gain is a risk seeking approach which makes choices based on achieving the maximum possible gain. Maximin gain and

minimax regret criteria are both risk averse and guide choices between alternatives away from potentially large losses regardless of potential gains. However, these theories aside, studies have shown that satisficing, a seemingly irrational process, is used in many decision situations. Satisficing occurs when the decision maker sequentially examines alternatives and selects the first one which meets one or more minimum criteria (38:209). At this point, the search and evaluation of alternatives stop, and "good enough" truly becomes "good enough". MacCrimmon and Wehrung proposed a variation of satisficing to explain risky decisions. They believed that decision makers have used a constraint and goal approach. Alternatives which have attributes that do not meet selected minimum constraints are discarded. The choice between the remaining alternatives is then based on how well one or more of the attributes best achieve a desired goal (36:173).

Simon (46) concluded that millions of variables can potentially affect people's decisions. These can be combined factorially and, when modified with the subjectiveness of the decision maker, it is easy to see where instances of bounded rationality are manifested in decision choices.

Good reasons can be given for supposing that evolutionary processes might produce creatures capable of bounded rationality. Moreover, a great deal of psychological research supports the hunch to which our introspections have led us, namely that this is the way in which human decisions - even the most deliberate - are made [46:104].

### Risk Taking Generalizations

Researchers have long attempted to make generalizations about individual risk propensities. Unfortunately, as has been shown by the variety of theories discussed above, there is no one standard way that people assess risk. Generally, researchers with this goal try to categorize people by how they view the basic components of risk and differentiate people as risk avoiders (risk averters) or as risk takers. MacCrimmon and Wehrung summarized these attitudes towards the components of risk (36:35). Risk avoiders generally require low maximum losses, few uncertain choices, more control, more information, and shared responsibility. Risk takers, on the other hand, accept higher stakes, many uncertainties, high exposure to losses, less control, and less information. The authors caution that different people will respond to seemingly similar risky situations in varying ways (36:36).

While it may be impossible to generalize absolutely over the population of all decision makers, it seems that a person's willingness to take a risk may be largely determined by physiological, psychological, and environmental factors. The sex of the person, for instance, has been correlated with risk-taking inclinations. In repeated sessions on computer-simulated tasks, men were observed to be more likely than women to make decision choices involving greater risks (28:204). Studies where military personnel were tasked to send tanks across

computer-simulated mine fields, showed that men were, again, generally more inclined to choose a risky course of action (27:135). These findings are in agreement with the general body of research on this subject (28:204).

Fourcade, Bougoant, and Martin used experimental games to test the effect of environmental elements and personality factors on decision making involving various levels of risk. They found very little correlation ( $r=.262$ , explaining 6.9% of the variance) between intellect and risk taking, but did find evidence that environmental factors influenced perceived risk, and found that a person's exposure to risk in his occupation affected the degree to which risk influenced many of his personal decisions (21:1-8). Further research again correlated these factors (35). Evidence shows that dispositional variables and situational variables interact, at times in conflict and, at other times, in concert to form risk-taking attitudes.

Among the numerous other findings, age is shown to inhibit risk taking, whereas a person's level of education has little effect (36:241-256). Nationalities and societal factors are also influences on risk. In fact, MacCrimmon and Wehrung cited two studies which showed that risk-related behaviors reflected a very strong cultural value in many instances (36:48).

MacCrimmon and Wehrung found that, among 509 executives, older executives with high seniority and at least one dependent were more risk averse. In this study,

however, they found that executives with post graduate education who filled positions of high authority were more risk seeking. The greater risk takers were the more successful managers and managers from small firms (36:247-263). Despite this, the executives tended to be risk averse overall and they believed they were greater risk takers than they actually were (36:225).

A survey of 300 Army officers elicited their risk taking propensities and concluded many of the same findings. When presented with five combat situations, high ranking, male, and line officers were more risk seeking than lower ranking officers, staff officers, or female officers (26:64-76+). Here, age was positively correlated to risk taking principally because age is significantly correlated to military rank and because the average age in this study was much younger than in the MacCrimmon and Wehrung study (32.5 years old (26:81) as opposed to 47.5 years old (36:70)).

Streufert and others cited studies where risk taking increased when the outcomes were a function of skill rather than chance (49:5). A person may enter a situation where skill will determine success before entering a situation left solely to chance, even though the latter case may have a higher probability of success. This idea implies that people who perceive a high internal locus of control (10:72) may be more apt to choose a riskier course of action than those who perceive a more dominant external locus of control.



Studies have linked psychological states with risk taking inclinations. Mental fatigue and high levels of information load stress have been shown to lead to increased risk taking (49:1-7). This finding is perhaps counterintuitive and shows that the psychological state of the decision maker may result in irrational decision choices.

An individual's perception of the environment fundamentally affects his decisions in risky situations. It is only natural that a person will choose a risky course of action if he perceives fewer risks involved in the outcomes than there actually are (49:5). To a supervisor, this implies that emphasis on rewards and positive outcomes can promote increased risk taking. At the same time, if less risk taking is desired, a person's behavior can be influenced by dwelling on the potential negative consequences.

Further, research has shown that risk averters display a more consistent behavior pattern than risk seekers (36:204). A person is also more likely to take a risk once involved in a situation than to take one to enter into a risky situation (36:177). Finally, risk taking becomes more pronounced in situations which have only losses as outcomes, high chances of a loss, and/or generally low stakes.

Dyer and Sarin reiterated why it is important to understand an individual's risk attitude. Besides self-enlightenment, knowledge about risk attitudes would better

explain how people make multicriteria decisions and would give insight into how preference aggregation rules are best employed in group decision making (15:875). They offered a contrast to the conventional measures of utility theory which they feel confound the determinants of risk propensities. Since risk taking is based on a person's preference for the outcome coupled with their view on risk taking, Dyer and Sarin have used methods to directly measure the latter attitude (called relative risk attitude). This gives an aggregate measure of an individual's attitude towards risk as it is currently structured by the physical, psychological, and environmental states.

#### Organizational Decision Making

Organizational risk taking on a strategic level has been analyzed and applied in nearly every military and business field. Strategic military operations become an iterative process of risk assessment and risk management. The decisions involved in deploying military troops including, for example, how many to deploy to a given area and how to resupply them, as well as every ensuing endeavor in battlefield tactics, must address a myriad of uncertainties. Similarly, issues concerning manning levels, dependence of transportation modes, maintenance, equipment availability, and other logistics considerations can never be planned with complete certainty.

An example of how risk issues are directly impacting a current logistics policy concerns where women can be assigned. The military's "risk rule" limits the jobs from which women can be excluded.

The new yardstick requires the Air Force to limit exclusions to those jobs involving risk of direct combat, exposure to hostile fire or capture, providing that the type, degree and duration of such risks are equal to or greater than the combat units with which they are normally associated within a given theater of operations [24:1].

The negative consequence referred to in the rule is the exposure to combat. The "risk" that the rule refers to is actually the probability of direct involvement in combat. Thus, women are to be excluded from positions which have a greater probability of entering combat situations than the position they are already filling. The services must assess the risks associated with each position and make this determination. The Navy, for example, has already stated that the risk (actually, chance) of direct combat to their "Seabee" mobile construction battalions is too great to allow women to be assigned to these units (56:38). An interesting question is whether these risk-related policies will be uniformly interpreted by subordinates.

Corporations in many industries base their livelihood and continued existence on the proper analysis and management of risky decisions in establishing corporate strategies. Probably more than anywhere else, these decisions mirror the classical axioms of decision making by maximizing long term utility and basing decisions on

actuarially sound probabilities. By their very nature, these decisions address long term goals and, therefore, can be based on "rational" decision making rules to maximize benefits. Industries and sectors whose bottom-line performances are based on risk-related decisions include military organizations, insurance companies, oil exploration companies, savings and loans, and medical practices. For example, an oil company must decide what to bid on an area of land or sea that is to be allocated by the government. The bid price is linked to both the assessed probability of striking oil and the likely revenues from marketing the oil (38:3).

A myriad of tactical and operational decisions involving risk are also made daily by individuals in these companies. Inventory policies, personnel issues, as well as decisions about purchasing, production, and transportation are fraught with uncertainty. Naturally, the upper echelons in these companies cannot directly control all the daily decision making. How these decisions are made, and specifically the role risk plays in influencing these decisions, is seldom addressed in the literature. Presumably, the military and private industry would like to know how middle and lower managers are treating risk and what influence upper management can have on daily risk-related decisions.

Grey and Gordon surveyed more than 900 managers to find, in part, if corporate goals convey to them a general

attitude towards risk taking (25:9-12). In many cases, managers in the same company who were aware of the corporate goals interpreted them very differently. Those managers with risk-taking propensities felt the stated corporate goals were too conservative; security-oriented managers, in contrast, believed the same goals to be highly ambitious. The authors did not comment on whether the corporate goals or established corporate policies had any affect on the managers' decisions involving risk. They did conclude, however, that the risk takers tended to rise to higher level jobs and, subsequently, hired other risk takers if the opportunity presented itself. Further, the risk seekers were motivated more by the need to make their own decisions rather than by making decisions to ensure continued employment and steady income (25:9).

It is recognized that the most identifiable determinants of risk to a decision maker are a lack of control, a lack of information, and a lack of time (36:14). Studies have found that most executives actively try to manage risks. When faced with risky decisions, executives attempt to adjust these risk determinants to make the situation more attractive. The most common means of risk adjustment are to seek additional information, to bargain, to delay a decision, or to delegate the decision (36:175). In other words, risk management techniques address the core determinants of risk.

Recent research has investigated a phenomenon in organizational decision making referred to as "risky shift". This typically refers to the notion that groups are more apt to make risky decision choices than individual decision makers. Slovic offered two possible explanations for this occurrence. First, he hypothesized that there is a diffusion of responsibility when groups make decisions. A poor decision cannot be attributed to anyone specifically. Second, risk taking is generally regarded as a higher cultural value than risk aversion (47:192). MacCrimmon and Wehrung supported the latter hypothesis. They found a strong cultural bias in favor of risk taking among the 509 executives they tested (36:227).

In further research on the risky shift phenomenon, there is evidence that the shift may work in both directions. In other words, while some groups may be far more likely to take a risk, other groups may be far more likely to make an ultra-conservative decision that avoids any chance of a risky outcome. Stein reported on studies that have found this polarization effect on group decision making (48:146).

Logistics Decisions. Many of the risk-related decisions that organizations must make center on the area of logistics. Logistics, as an integrated discipline, has been viewed with increasing importance in recent years (44:72-77).

Emmelhainz studied the effect of risk and uncertainty on trade-offs involved in logistics decision making (19). He presented subjects with various alternatives where the annual costs and order cycle times (representing customer service) of the alternatives varied in both magnitude and degrees of uncertainty. Relative losses were possible outcomes; hence, risks were involved in some of the decision alternatives. For example, the order cycle time could be presented as a 100% certainty that it would be a 1.4 days increase (an undesirable consequence); or it might be presented as a probability distribution over the range of a .4 days increase to a 2.0 days decrease. Further, and most germane to this thesis, Emmelhainz presented some of the participants with an overall objective (i.e., minimize total cost, maximize profit,...) and measured the influence of the objective on the evaluation of the alternatives.

The study showed that uncertainty and risk had a significant influence on assessing the cost and service variables. Managers treated uncertain logistics alternatives differently than those stated in certain terms (19:247). Generally, the influence of uncertainty lowered the evaluations of the alternatives (19:249); however, this was not the case across all interactions of independent variables. For example, a service variable that was presented as 100% certain was rated higher than uncertain service except when the objective was to minimize cost, and service was a relative loss. Further, the study agreed with

prospect theory when potential gains were presented. That is, uncertainty would lower evaluations. On the other hand, Emmelhainz found there was inconclusive evidence as to the effect of uncertainty on potential losses (19:236). Prospect theory had predicted that uncertain losses would be preferred over certain losses.

Finally, the objective given to the participants interacted significantly with most of the combinations of the independent variables. For instance, when cost was represented as a gain, service uncertainty lowered responses significantly more when service was the objective than with all other objectives (19:241). A given objective influenced the role that risk played on the evaluation.

Only recently has the military begun to recognize the extreme importance of risk assessment in logistics decision making. Cost overruns and inadequate supportability spurred an increasing focus on formalizing assessment of risks. Previous efforts to accommodate risk analysis within DoD met with substantial resistance.

Although there are inherent difficulties in communicating risk information, the primary difficulties in the Department of Defense (DoD) are presented by a system of compartmental decision making that is steeped in tradition, power structures and resistance to change [6:225].

This bureaucratic resistance, however, is changing.

Nowhere is risk information being used more in DoD than in systems acquisition. Decision support systems which address the fundamental problems associated with risk



inherent decisions are being widely used in the military acquisition process. Swank and Wales have reported that decision support to evaluate acquisition risks have been employed in more than seventy applications (51:43). In addition to assessing and analyzing risk-related decisions, these efforts are providing means for management of risk and for risk control (22:184). The concept is only now taking root as other important potential benefits of risk analysis are being discovered.

Reliability, defined as the probability that an item will function in some operational environment under stated conditions (11), is an important logistics consideration in the acquisition process. The Air Force has recently instituted policies to increase the weight given to reliability issues in making many logistics decisions. Acquisition decisions, for instance, have historically been based on cost, delivery schedule, and product performance. Subsequent product reliability was typically relegated to an afterthought. Amendments to Air Force Regulation 70-15 present guidance which changes this way of thinking. The amendments mandate that increased weight be given to reliability concerns (12) and, in effect, establish reliability issues as coequal in importance with cost, schedule, and performance.

Unfortunately, recognition of reliability implications has somewhat complicated many decisions. Reliability issues are often clouded in uncertainty and contain potential

pitfalls; hence, risks are present. For instance, a given item's reliability may be expressed as a probability distribution (i.e., an exponential distribution). A flying wing may likely base its maintenance policy for a given item on a given probability distribution. If, for example, an item has a reliability of .99 until a scheduled preventive maintenance action, there is still a one percent chance of failure before this maintenance action. Since the probability distribution cannot perfectly predict failure rates, this figure may be slightly in error. The planned maintenance action, therefore, is based on a probability which was derived from an inexact distribution that can only predict reliability rates in some confidence interval (4:39). Not only is uncertainty an inherent part of this issue, but the maintenance policy had already provided for a given possibility (one percent in this example) of failure; again, the presence of risk is manifested.

The Army uses risk assessment in determining realistic budgets (42:29) and research and development (R&D) funding (3:41). In 1975 they instituted a program called Total Risk Assessing Cost Estimate (TRACE). It uses probabilistic event analysis to project cost growth for R&D programs. TRACE now plays an important role in the Army's acquisition strategy (3:43).

Finally, risk assessment is not limited to the acquisition arena. For example, Schmidt related wartime success with sound assessment of high-risk decisions

(41:34). Operational decisions result from strategic aims, battlefield information, risk assessment, and combat tactics. Risk assessment is portrayed as the key element in the decision process. Certainly, history proves that battlefield success has been an explicit function of how well military leaders have made risk-related decisions.

Two recent events in the Persian Gulf contrast how risk is perceived and how a person might respond to it. In May 1987, a U.S. Navy frigate, the USS STARK, was shot by a missile fired from an Iraqi aircraft. The aircraft had been tracked on radar by the STARK for more than 200 miles, and was issued repeated warnings on the radio. Despite having several defense options (SM-1 missiles, anti-aircraft guns, chaff, a close-in weapon system), the captain delayed his decision until the aircraft was 12 miles away. It was too late for effective defense and the STARK was hit by the missile (54:16-24). In July 1988, a U.S. small cruiser, the USS VINCENNES, tracked an aircraft departing an Iranian airport on its sophisticated Aegis radar. Believing the aircraft to be hostile, the captain, again after repeated warnings, ordered the aircraft to be shot down (9:19).

Tragically, the aircraft was an Iranian airliner. The STARK had more indications (speed, altitude,...etc.) indicating that the tracked aircraft was hostile, yet did not respond to the apparent risk. The VINCENNES either perceived more risk than there actually was or responded far differently to much less of a risk. It is unknown as yet how much these

actions were influenced by guidance from higher command authority, but such knowledge could aid leaders in establishing guidance to influence similar future events.

### Summary

This chapter reviewed the pertinent literature concerning many of the risk-related issues. Basically, the term risk denotes a situation where outcomes are uncertain and there exists a possibility to experience a loss. Decision making that maximizes utility, while seemingly rational, is repeatedly violated. Explanations such as prospect theory and regret theory attempt to explain these violations. Other theories hold that the framing of the decision will induce predictable, albeit illogical, decision responses. Research also shows that a person's physical and psychological states affect how risk is viewed and how subsequent decisions are made.

This chapter also examined the importance of considering risk in a military context. The field of military logistics, in particular, must address risk-related issues on a continuing basis. While some actions have led to a heightened awareness of the role of risk, there still exists a void in the knowledge of how risk is actually being perceived and which policies might influence those perceptions. In fact, very little is known about how logistics managers are responding to these risks or whether

any organizational policies are influencing their decisions  
on risk-related issues.

### III. Methodology

#### Introduction

The overall purpose of this research was to determine whether management policies can influence how logistics managers make decisions involving risk and uncertainty. The logistics managers were presented with an acquisition decision in which they were asked to evaluate 16 computer systems based on cost and reliability data. An analysis of their responses was used to determine how risk affected their decisions and what role management's policy played in their decision evaluation. This chapter describes the general experimental design, then states the research hypotheses and the anticipated reactions. This is followed by a three phase description of how the research was conducted beginning with the pretest, followed by the data collection method and discussion of the test subjects, and concluding with the method used for data analysis. This chapter also states the controls used throughout the research process.

#### Experimental Design

This thesis used a post-test-only control group design (20:122). Five independent variables were used in a mixed design to achieve both within-subject and between-subject manipulation within the acquisition setting. The

evaluations made by each test participant resulted in four dependent variables.

Independent Variables. Four independent variables accounted for the within-subject variability in the experiment. Two levels each of cost, cost certainty, reliability, and reliability certainty were combined to produce the 16 distinct alternatives that each test participant evaluated. Cost was presented as the one-time acquisition cost of a data automation and decision support computer system and had two levels. Cost could be a relative gain or relative loss compared to a budgeted amount of \$100,000. Reliability was represented as the percentage of time the system was expected to be available for use (uptime). It also had two levels: a relative gain or a relative loss compared to an industry average of 90 percent.

Cost certainty and reliability certainty had two levels as well. Data were presented as either certain (i.e., a 100% chance of occurring) or uncertain (where the outcomes were given over a discrete probability distribution). Figure 1 shows the 16 combinations of these four variables. Each cell represents one of the 16 alternatives that each decision maker evaluated.

		1	2	3	4
Cost	Positive				
	Uncertain	5	6	7	8
	Certain	9	10	11	12
	Negative				
	Uncertain	13	14	15	16
		Certain	Uncertain	Certain	Uncertain
		Positive		Negative	
		Reliability			

**Figure 1. Combinations of Within Subject Variables**

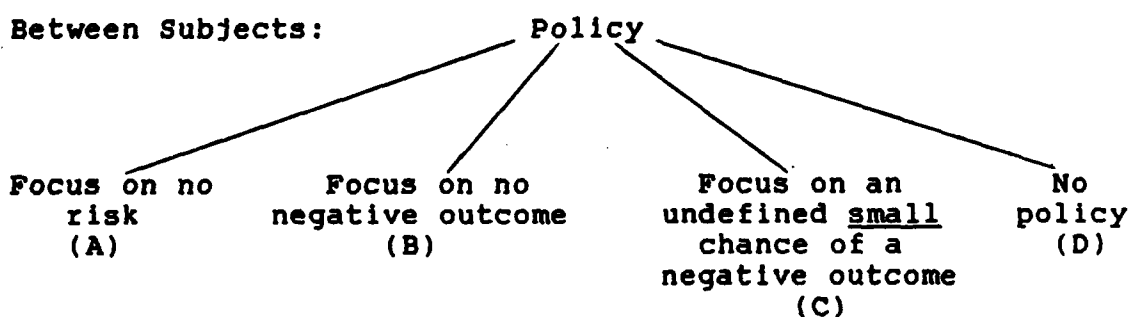
The policy variable was the fifth independent variable and it represented the between-subject factor. Policy was presented in four levels. Assignments of test participants were randomly made to four test groups. One group acted as the control group; the other three groups were given a management policy in the form of guidance from their supervisors regarding how to treat risk and uncertainty in making their decisions (the specific guidance statements were presented in Chapter I; summary labels are in Figure 2).



Overall, the mixed experimental design manipulated the five independent variables in the following manner:

( 4 )                      x                      ( 2 x 2 x 2 x 2 )  
Between Subjects                      Within Subjects

Figure 2 depicts the levels of each of the independent variables.



Within Subjects:

<u>Variable</u>		<u>Levels</u>
Cost	:	Positive or negative
by		x
Cost Certainty	:	Certain or Uncertain
by		x
Reliability	:	Positive or Negative
by		x
Reliability Certainty	:	Certain or Uncertain

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Figure 2. Levels of the Independent Variables

Dependent Variables. Four dependent variables were produced as a result of the evaluations. The test participants were asked to rate each alternative (from 1-100), estimate each alternative's cost and reliability, and rank order (1-16, 1 being best) the sixteen alternatives. These four evaluations were a function of the five independent variables already discussed.

### Hypotheses

The primary emphasis of this research was to examine the effects that management policies would have on a risk-related logistics decisions. Generally, it was believed that the policies would significantly influence how logistics managers evaluated proposals which incorporated varying degrees of risk. The research design also allowed other hypotheses to be tested based solely on within-subject variable manipulation. The specific hypotheses and the anticipated direction of the results are presented below.

Hypothesis 1: Policy, cost, cost certainty, reliability, and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

It was expected that this five-way interaction would be significant for several reasons. For example, when both cost and reliability were negative and certain, the participants under Policy B guidance should have rated these alternatives lower than the other three groups since Policy

B permitted absolutely no negative outcomes. Also, when both cost and reliability were positive but uncertain, participants in the Policy C group should have rated these alternatives higher than those guided by Policy A or Policy B. This is because Policy C specifically allowed for decisions which had a small chance for a negative outcome; Policy A and Policy B permitted no risk-taking and should, therefore, have viewed positive, but uncertain, data less favorably.

The five-way interaction is important because significant higher level interactions imply that the main effects and lower order interactions are less important in basing the decisions (33:54). For example, the evaluations were expected to be significantly affected by the levels of cost and the levels of reliability. However, if cost or reliability were also involved in a significant higher level interaction, the importance of their main effects are lessened in gaining a more complete understanding of how variables influenced logistics decisions.

Hypothesis 2: Cost and cost certainty will interact to significantly affect the evaluations of logistics alternatives.

Hypothesis 3: Reliability and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

When cost is positive (i.e., a gain), alternatives stated in certain terms should be rated higher. When cost was negative, alternatives stated in certain terms should

have been rated lower. The same anticipated direction applies to reliability and reliability certainty. These effects are based on the predictions of prospect theory (30:454). In a similar research design, Emmelhainz showed that positive certainty was indeed rated higher in logistics decisions, but that no significant difference could be stated when negative certainty was compared to negative uncertainty (19:236).

Hypothesis 4: Policy and cost certainty will interact to significantly affect the evaluations of logistics alternatives.

Hypothesis 5: Policy and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

Since Policy A permitted no uncertainty, evaluations of alternatives which were presented in uncertain terms should have been evaluated significantly lower than those presented in certain terms. This should have been true despite the fact that the uncertain alternatives had the same expected value as the certain ones and included some chance for improved cost or reliability. Policies focusing instead on consequences or on small levels of risk, should result in different evaluations.

Hypothesis 6: Policy, cost, and cost certainty will interact to significantly affect the evaluations of logistics alternatives.

Hypothesis 7: Policy, reliability, and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

Policy B stated that no negative outcome was acceptable. Any alternative with any chance of a loss should have been rated lower by those guided by Policy B than by those subjected to other guidance. In contrast, since Policy C allowed for a small chance for a loss, the alternatives which were positive but uncertain should have been evaluated higher than for the other policies despite there being a chance of a loss. The pattern should be the same for cost and reliability with the policies, assuming cost and reliability are perceived as equally important by the test subjects. If they are not, a four- or five-way interaction will occur.

The analysis also tested all other two-, three-, and four-way interactions for significance. Significant interactions meant that different levels of one or more independent variables resulted in different assessments of the dependent variables. Relevant conclusions can be drawn from analyzing such interactions. For instance, policy may have interacted with the levels of cost certainty only when cost was positive and reliability was certain. While this becomes complicated, logistics decisions may, in fact, be affected by such considerations. Emmelhainz discovered these types of interactions between six independent variables in a logistics decision experiment (19:113-197). Unlike his research, however, this research was specifically interested in analyzing the possible interactions between the variables presented in Hypotheses 1-7, with a focus on

gaining a better understanding of how to manage the role of risk and uncertainty in logistics decision making.

### Conducting the Research

The research portion of this thesis was conducted in three general phases. The first phase involved the pretest activities which were used to revise the experiment that was administered in the second phase. Phase two was the actual data collection from the logistics managers, specialists, and graduate logistics students selected to participate in the experiment. Finally, phase three involved the statistical analysis of the data.

Phase One: Pretest. The experiment was designed to include three sections: an introduction, the task of rating the proposal alternatives, and a questionnaire. The introduction ranged from three to three and one-half pages (depending on the policy). It presented the acquisition situation as well as brief discussions about cost, reliability, and uncertainty. Four examples of proposal alternatives were included in this section to provide the test participants with the general format of the proposals and provide the scope of the data they would be evaluating. The four separate introductions are included in Appendix A.

The second section presented the test participants with the 16 alternatives and asked the logisticians to rate each proposal on a scale from 1 to 100 then project what the actual cost and reliability of each particular system would

be. The sixteen alternatives were randomly ordered to ensure that no two people found the 16 alternatives in exactly the same sequence. Once they completed rating each proposal, the experiment directed them to remove the proposals from the notebook and then order them from 1 to 16 in order of preference. This accomplished two important results. Principally, it forced the subjects to reexamine each alternative and reevaluate the ratings they originally assigned. Since changes were permitted at any time, a second examination of the alternatives would likely achieve a more accurate assessment. Secondly, an ordinal ranking of the 16 alternatives allowed (in fact, mandated) the participants to break any ties in the ratings. This also permitted an ordinal analysis of the data. Appendix B contains the second section.

The third section was a questionnaire (see Appendix C) that was to be filled out after completing the evaluations. The questionnaire queried the logisticians about the perceived realism of the experiment, the level of difficulty encountered in manipulating the data, and their opinions on the importance of cost and reliability factors. Questions were also asked to determine if they could remember the guidance given to them about risk and uncertainty. Risk-related scenarios to test risk biases developed and used by Kahneman and Tversky (30), and later by Emmelhainz (19), were used to test risk biases. Finally, questions were

asked to establish the participants' demographics including age, background, and logistics experience.

The pretest was given to nine participants primarily to evaluate their comprehension of the instructions and the task. As a result of the pretest, the instructions were shortened, the supervisor's guidance was underlined, and the guidance was restated prior to the evaluation section of the test. Minor changes to the format of the proposal alternatives were also made as a result of the pretest feedback. Finally, the pretest established that approximately 45-50 minutes were required to complete each experiment.

Phase Two: Data Collection. The test participants were selected from populations of logistics managers, specialists, and graduate logistics students. The logistics managers and specialists were selected from those enrolled in Professional Continuing Education (PCE) courses at the Air Force Institute of Technology (AFIT). The logistics students were attending the AFIT masters program in logistics management and were full-time graduate students with varying backgrounds. The graduate students were all active duty military personnel or DoD managers who had come to AFIT with field experience either in a logistics or operational field. They all possessed managerial and leadership experience. All of the students had previously been exposed to overviews of many logistics disciplines as



well as some further instruction on several logistics fields and issues.

The experiment was administered in several sessions to groups ranging in size from one person to 24 participants. The different group sizes resulted from time constraints and conflicting schedules; however, the test group sizes were assumed to have no bearing on the performance of the experiment since random assignment to each of the 4 policies was accomplished in each session. The experiments were administered during the period of 11 July to 22 July 1988.

Phase Three: Data Analysis. The mixed experimental design permitted a five-factor analysis of variance (ANOVA) using a split-plot design for repeated measures to test the research hypotheses (16:333-349). The split-plot design accounts for both between-subjects factors (policy, in this thesis) and within-subject factors (i.e., cost, cost certainty, reliability, and reliability certainty). Edwards showed that this method of analysis is appropriate.

The experiment we have described is a repeated measure split-plot design in which subjects are randomly assigned to the levels of A [between-subjects factor], or vice versa, and each subject is then tested under all levels of B [within-subject factors] in a random order [16:334].

AFIT's computer system had access to statistical software with the capability to perform five-factor ANOVA split-plot analysis using a standard statistical package (39:132,193).

## Controls

Several controls were used to ensure the validity of the experiment. The assignment of logisticians to each of the test groups met the following two assumptions which satisfy split-plot design requirements. First, the assignment of test subjects to a particular group was random, independent of other assignments, and irrespective of the test group size. Second, with respect to average risk-taking dispositions, each group's probability distribution was assumed to be normal due to the random assignments. It was not necessary to test for equal variances between subjects (sphericity) or within subjects (homogeneity). Homogeneity was obviated since all of the within-subject factors had only two levels (33:45). Further, the split-plot design was based on the most conservative F-test (16:338-349) which is robust against all violations of normality and homogeneity and is also robust against extreme violations of sphericity (16:338).

Random assignments to the four groups also constituted the primary means of ensuring equivalence between the control group and the three groups subjected to the policy treatments (20:76). The participants, regardless of whether they were from the PCE courses or were full-time AFIT graduate students, had an equal chance of being assigned to any one of the four test groups.

The 16 alternatives were also presented to each test participant in a random order. This equalized any rating

biases that may have resulted due to the order in which the proposal alternatives were presented.

Finally, identical verbal instructions were given at the beginning of each test session regardless of the size of the test group. Once the exercise began, individual questions were entertained on a one-to-one basis. Appendix E contains the instructions given to all the participants.

Chapter IV presents the results of the data analysis.

#### IV. Analysis

This chapter presents the analysis of the data collected from the thesis experiment. It describes how the data were collected from the subject responses, explains why some responses could not be used in the data base, and describes some of the difficulties encountered in performing the statistical analyses. The chapter then presents the results from testing the various interactions described in Chapter III, examines the analyses relevant to the seven research hypotheses, and analyzes the findings from other significant interactions.

##### Subject Responses

The thesis experiment was administered to 117 participants. It was given to 89 logistics managers and specialists attending PCE courses and to 28 full-time graduate logistics students. The dates and group sizes that participated in the experiment are summarized in Table 3.

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Table 3. Test Dates and Test Group Sizes

<u>Date</u>	<u>Group Size</u>	<u>Date</u>	<u>Group Size</u>
11 July 88	23 (PCE)	13 July 88	3 (GRAD)
12 July 88	24 (PCE)	14 July 88	1 (GRAD)
12 July 88	17 (PCE)	14 July 88	2 (GRAD)
12 July 88	5 (GRAD)	14 July 88	2 (GRAD)
12 July 88	1 (GRAD)	14 July 88	2 (GRAD)
12 July 88	1 (PCE)	15 July 88	15 (PCE)
12 July 88	3 (PCE)	15 July 88	4 (GRAD)
13 July 88	5 (PCE)	19 July 88	1 (GRAD)
13 July 88	1 (GRAD)	21 July 88	4 (GRAD)
13 July 88	2 (GRAD)	22 July 88	1 (GRAD)

Assignments to the test treatment groups, as distinguished by the four levels of Policy (A, B, C, and D), were random and, consequently, the sample sizes assigned to each policy were unequal. The experiment was administered to 28 subjects given Policy A, 30 subjects given Policy B, 28 subjects given Policy C, and 31 subjects given Policy D. Within these totals, AFIT graduate students represented seven responses in each group.

Seven of the experimental responses had to be withheld completely from the data base. This was done only after it was obvious that the instructions were misunderstood or the test subject's evaluations were completely inappropriate. One test subject completed the cover sheet and worked the examples in Section I of the experiment but did not proceed any further. Two of the test subjects admitted that they were confused by the probability distributions or the format of the experiment and expressed the opinions that their answers were not valid. Two other subjects' responses demonstrated repeated and exaggerated inconsistencies in logic. For example, one subject rated an alternative as a "50" and ranked it third best. This was followed by a rating of "1" (ranked fourth), a rating of "100" (ranked eighth), and a rating of "60" (ranked tenth). The ratings and rankings were clearly illogical and the excessive inconsistencies invalidated these data; both were removed from the data set.

Obvious and excessive inconsistencies further eliminated the two other experiment responses that were not included into the data base. These subjects were basing decisions on expected costs and expected reliabilities that were impossible to attain given the data presented. Apparently, they failed to understand the task they were given.

A net total of 110 responses were, therefore, used to establish the data base. Within these 110 responses, some of the dependent variables had to be treated as missing values. Either the data were, in fact, missing (i.e., the subject failed to answer one of the questions) or the responses were presented in an ambiguous form. The most common ambiguity was showing the expected cost or expected reliability as being "less than" or "greater than" a particular value rather than a specific number. For example, the responses in this class said the expected cost would be: "< \$100,000"; or the expected reliability would be: "> 90%". Another error that occurred twice was evaluating the expected cost or reliability on a 1 to 100 scale instead of estimating their actual raw values. These responses were treated as missing values. Table 4 presents the final composition of the data base. The invalid responses were deleted from the total sample sizes yielding the net usable sample sizes. The ANOVAs then deleted the records where a missing value represented a variable of interest for the particular analysis.

Table 4. Data Base Composition

<u>Test Group</u>	<u>Total Sample Size Tested</u>	<u>Number Deleted From Data Base</u>	<u>Net Usable Sample Size</u>
Policy A	28	2	26
Policy B	30	1	29
Policy C	28	1	27
Policy D	31	3	28

Missing values for each dependent measure:

	<u>Ratings</u>	<u>Ranks</u>	<u>Expected Cost</u>	<u>Expected Reliability</u>
Policy A	2		2	2
Policy B			2	2
Policy C	1		4	4
Policy D	1	1	5	6

Due to the missing values, the analysis of variance on the dependent variable, rating, for example, used a sample size of 106 (110 minus the 4 missing values) to test all interactions. The analyses on the other dependent variables were affected in a similar manner.

Minor inconsistencies (one or two approximately equal ratings in reverse order) between an alternative's rating and rank were found in 21 of the 110 usable subject responses (19.1% of the experiments). This was not

unexpected. In a similar experimental design used by MacCrimmon, 47 percent of the respondents had these "choice instabilities" between the ratings and rank order of only four alternatives (36:7). Since the experiment used in this thesis asked that 16 alternatives be rank ordered, it was understandable that 19.1 percent of the responses contained minor choice instabilities. It also demonstrates that many of the test subjects were actually reevaluating the alternatives to determine the rank order, and not merely arranging them based on the ratings they had already assigned. This fact, coupled with the observance that many test subjects changed their original ratings upon reinspection, lends confidence to the assumption that the rankings and ratings were a true reflection of how the subjects might respond had this situation been a real-life tasking. In addition, the subjects were observed during the task as obviously concentrating, comparing, and evaluating each alternative.

### Statistical Analysis

As discussed in Chapter III, a split-plot repeated measures design was used to perform the analysis of variance. This design was appropriate for repeated measures analysis but is extremely uncommon in the research literature. In fact, LaTour and Miniard suggested that repeated measures analysis has often been incorrectly performed and is generally misused (33:45-55). Examples,



therefore, of split-plot designs were found infrequently in the literature. From the sources reviewed, only Emmelhainz had an experiment of comparable complexity.

The SAS statistical software package can accommodate a split-plot design using either its PROC GLM or PROC ANOVA features. The PROC GLM analysis is designed for experiments with unequal sample sizes between treatments (unbalanced data). PROC ANOVA, on the other hand, is more appropriate for balanced data sets. Unfortunately, while running the analyses on all three-way or higher interactions presented in this thesis, the AFIT computer's internal memory storage dedicated to SAS was exceeded using PROC GLM. In fact, the five-way interaction would have required 324 megabytes of internal storage but could access only the 16 megabytes dedicated to running SAS programs (39).

PROC ANOVA, however, uses more liberal assumptions and makes more efficient use of computer memory. PROC ANOVA can be used in lieu of PROC GLM provided the treatment sample sizes are sufficiently large (all  $n$  greater than 20) and are approximately equal (33:51; 45). It then becomes a matter of correctly identifying the error terms and degrees of freedom to be used in both the numerator and the denominator of the  $F$ -statistic (16:334-349). This thesis used the PROC ANOVA feature and specified the most conservative  $F$ -test statistic. As a partial check, all one-way and two-way interactions were analyzed using both PROC ANOVA and PROC GLM. The results in each case were identical.

### Analysis of Variance

An analysis of variance was performed on the dependent variable, rating, based on all possible interactions of the independent variables: cost, cost certainty, reliability, reliability certainty, and policy. The objective of the analysis was to determine whether the levels of the independent variables or interactions between the levels of independent variables significantly affected how the test subjects rated the proposal alternatives in the thesis experiment. As discussed in Chapters I and III, the policy variable represented the between-subject factor while the four other variables represented the within-subject factors. Although the primary emphasis of this research was to determine if policy interacted with the other variables, all possible combinations (a total of 31) of the independent variables were analyzed. Table 5 includes the ANOVA results.

### Analysis of the Hypotheses

The seven research hypotheses are presented here in the order they were discussed in Chapter III. Additional findings that are relevant to the research topic are also discussed following the analyses of the hypotheses.

Hypothesis 1: Policy, cost, cost certainty, reliability, and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

The ANOVA on the five-way interaction showed that the hypothesized effect did occur ( $p=.0408$ ). The four levels of policy interacted with the two levels each of cost, cost certainty, reliability, and reliability certainty to affect

Table 5. ANOVA Results for All Interactions of the Independent Variables

Dependent Variable: Rating

<u>Source of Variance</u>	<u>F-Value</u>	<u>Tail Probability</u>	<u>Significant (Alpha=.05)</u>
Policy (POL)	1.13	.3391	
Cost	309.78	.0001	Yes
Cost Certainty (CC)	18.87	.0001	Yes
Reliability (REL)	187.12	.0001	Yes
Reliability Certainty (RC)	42.15	.0001	Yes
POL*Cost	1.55	.2054	
POL*CC	4.18	.0078	Yes
POL*REL	2.50	.0638	
POL*RC	5.03	.0027	Yes
Cost*CC	26.39	.0001	Yes
Cost*REL	16.72	.0001	Yes
Cost*RC	0.85	.3589	
CC*REL	2.50	.1168	
CC*RC	0.81	.3698	
REL*RC	17.25	.0001	Yes
POL*Cost*CC	4.41	.0058	Yes
POL*Cost*REL	3.76	.0131	Yes
POL*Cost*RC	0.74	.5317	
POL*CC*REL	0.71	.5494	
POL*CC*RC	1.29	.2826	
POL*REL*RC	3.10	.0301	Yes
Cost*CC*REL	2.12	.1483	
Cost*CC*RC	0.27	.6055	
Cost*REL*RC	3.82	.0532	
CC*REL*RC	4.24	.0421	Yes
POL*Cost*CC*REL	4.00	.0097	Yes
POL*Cost*CC*RC	0.74	.5320	
POL*Cost*REL*RC	0.33	.8072	
POL*CC*REL*RC	0.82	.4831	
Cost*CC*REL*RC	0.43	.5119	
POL*Cost*CC*REL*RC	2.86	.0408	Yes

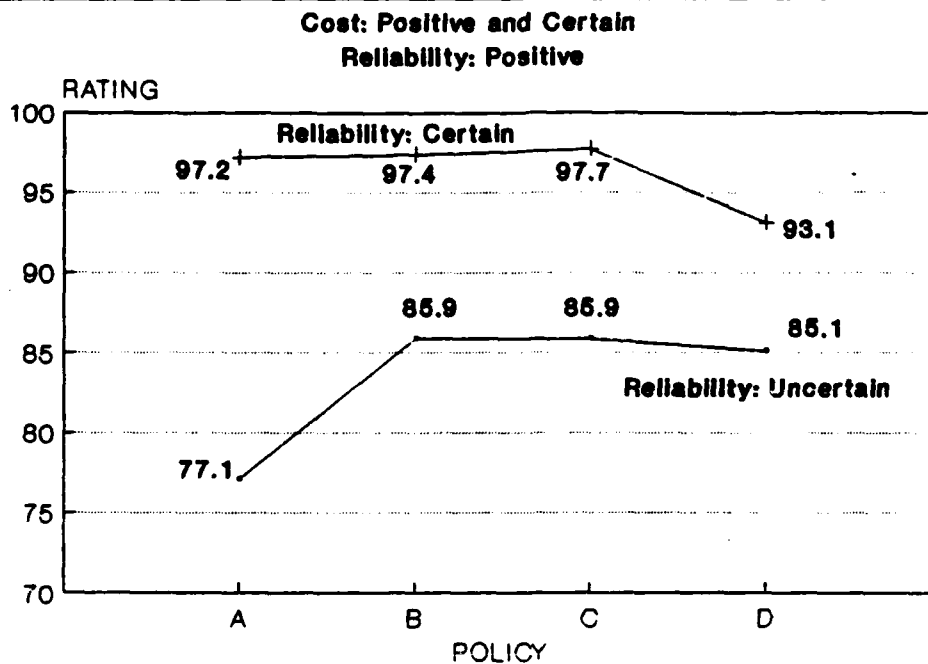
how the logisticians rated the proposal alternatives. Figures 3a-3h present a graphical illustration of this interaction. The most comprehensive and accurate illustration ideally would be a graph presented in six dimensions; however, since this is impossible to depict, Figures 3a-3h show the means for all levels of the 5 independent variables in a series of two dimensional graphical representations. The variables are grouped and presented in a logical fashion, yet some interactions can only be seen by comparing more than one figure. Generally, significant interactions are best seen on these graphs when the two lines deviate from being approximately parallel. Following each set of graphs an explanation will describe the major sources of interaction.

Hypothesis 1 predicted the significant interaction between the five independent variables. This five-way interaction shows the complexity with which the independent variables were viewed and evaluated in the experiment. Differences in rating the alternatives were not based solely on any of the five main effects or only on lower order interactions. The fact that the ratings were influenced by changing one level for one variable when all other variables were held constant reveals the significant role that the five-way interaction played. Its significance somewhat mitigates the importance of lower order interactions and makes them, in part, subordinate to the five-way interaction. In other words, while analysis of the one-,

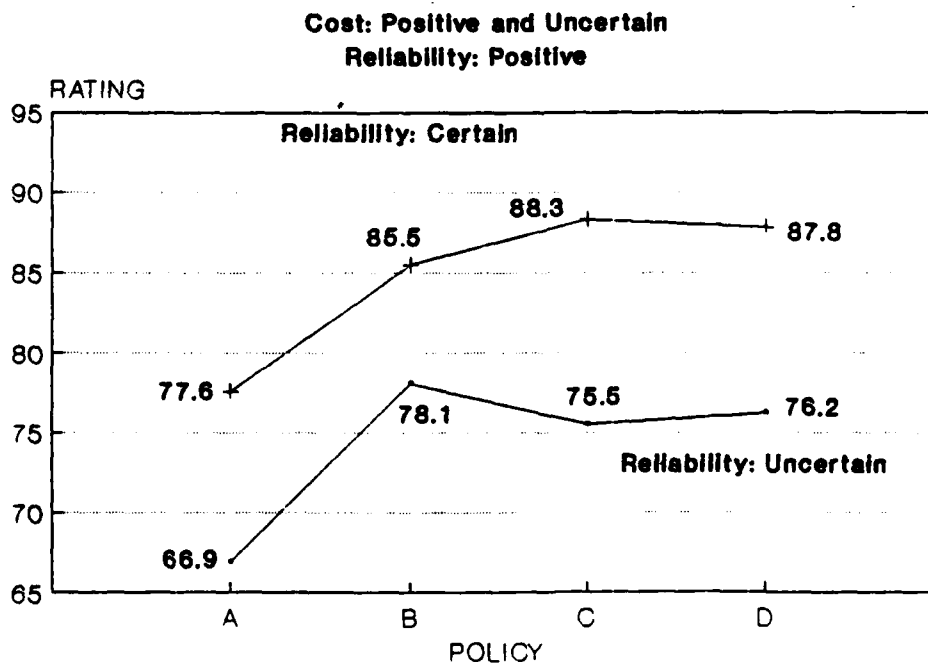
two-, three-, and four-way interactions are enlightening and useful, their significance can more accurately be explained by examining the influences of the five-way interaction.

To understand the complexity of the five-way interaction requires that the figures which follow be reviewed in detail in conjunction with the narrative. The major emphasis will be on Figures 3c, 3f, 3g, and 3h. Figures 3a and 3b show that very little difference occurred when cost and reliability were positive. However, when reliability was negative and cost was certain (Figure 3c), the Policy B test group rated alternatives with uncertain reliability more favorably. Policy B stated that no negative outcomes were allowed; therefore, since uncertain reliability presented a chance of a positive outcome, it was rated significantly higher. Interestingly, this interaction did not occur when, instead, positive reliability was held certain and the levels of cost certainty varied (Figures 3a and 3b, combined).

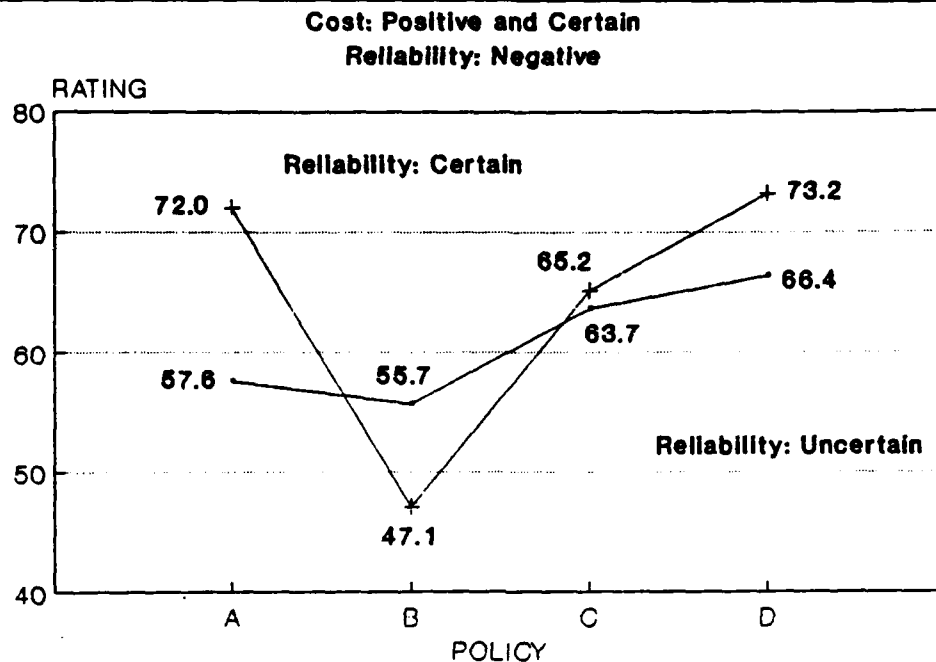
Figure 3f indicates that, under the stated conditions, Policy A and Policy C subjects rated certain reliability relatively higher than uncertain reliability, compared to Policy B and the Policy D control group. The Policy A (no uncertainty) ratings were expected; Policy C, however, allowed for a small chance of a negative outcome. Positive reliability that was uncertain still had a 10% chance of a .82 reliability rate and a 20% chance of a .87 reliability rate. Apparently a 30% chance of a negative reliability was



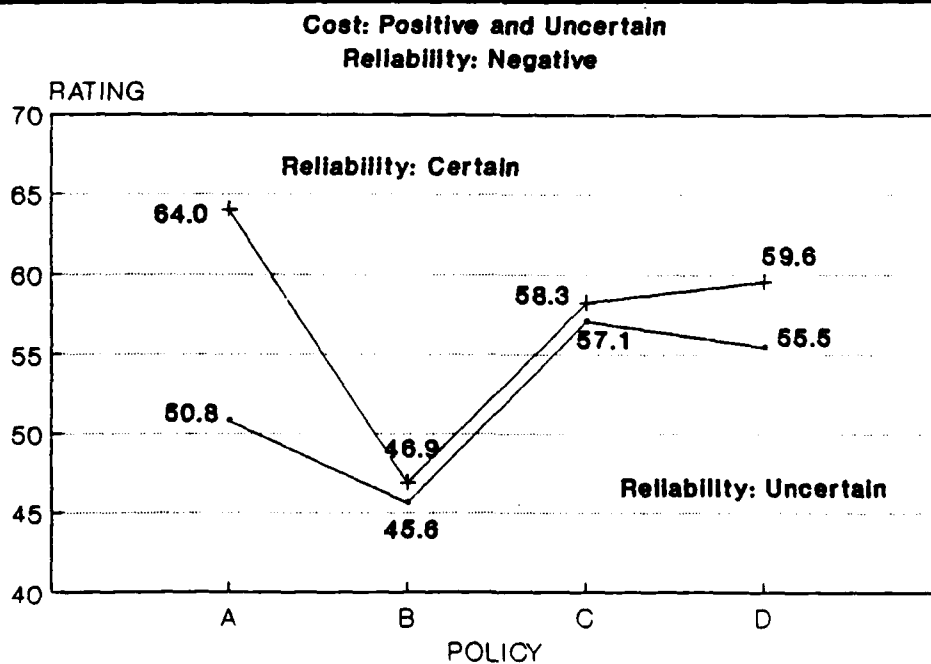
**Figure 3a. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part a)**



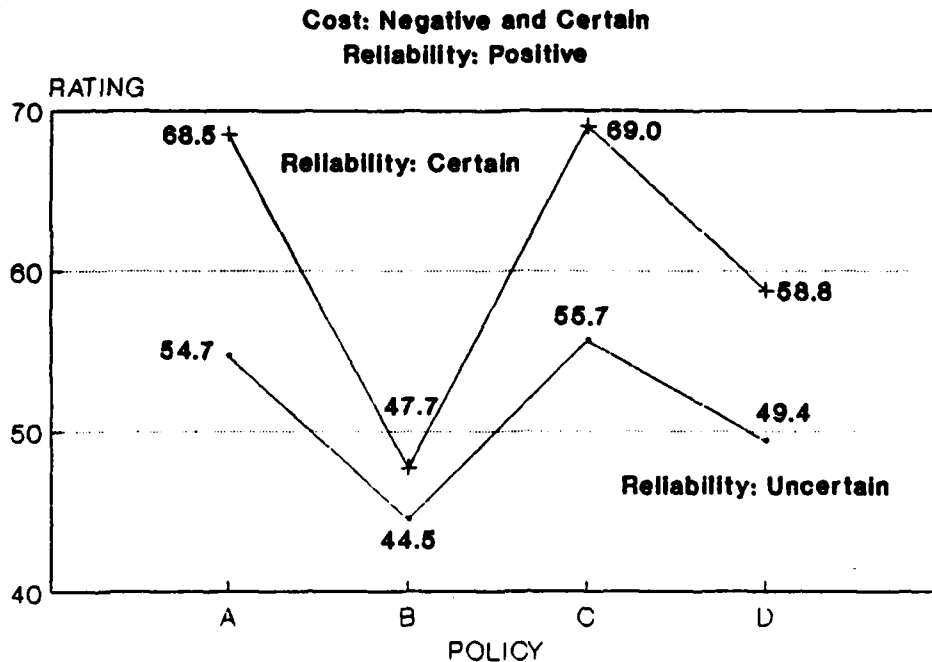
**Figure 3b. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part b)**



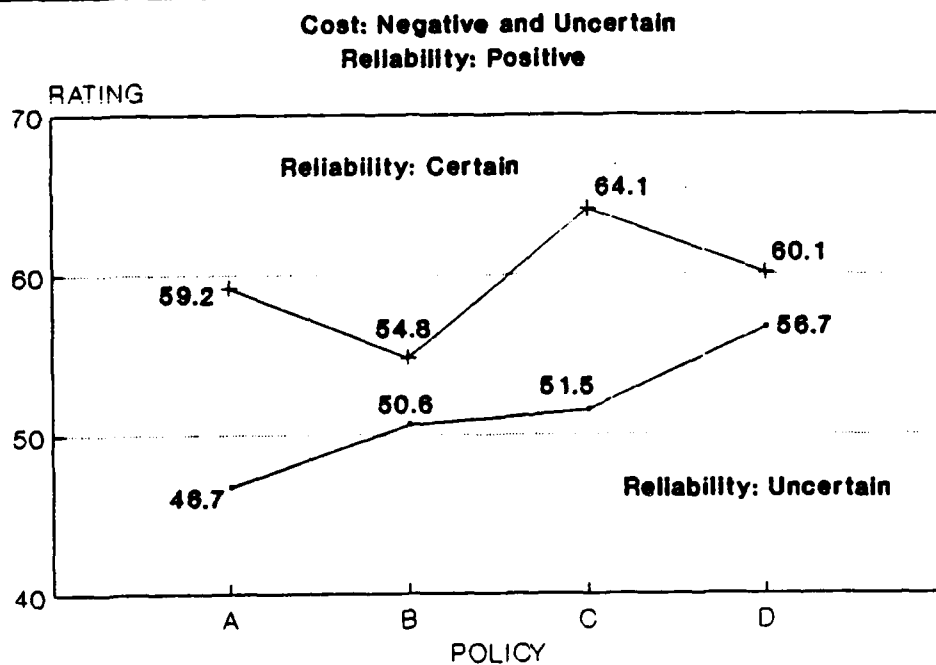
**Figure 3c. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part c)**



**Figure 3d. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part d)**

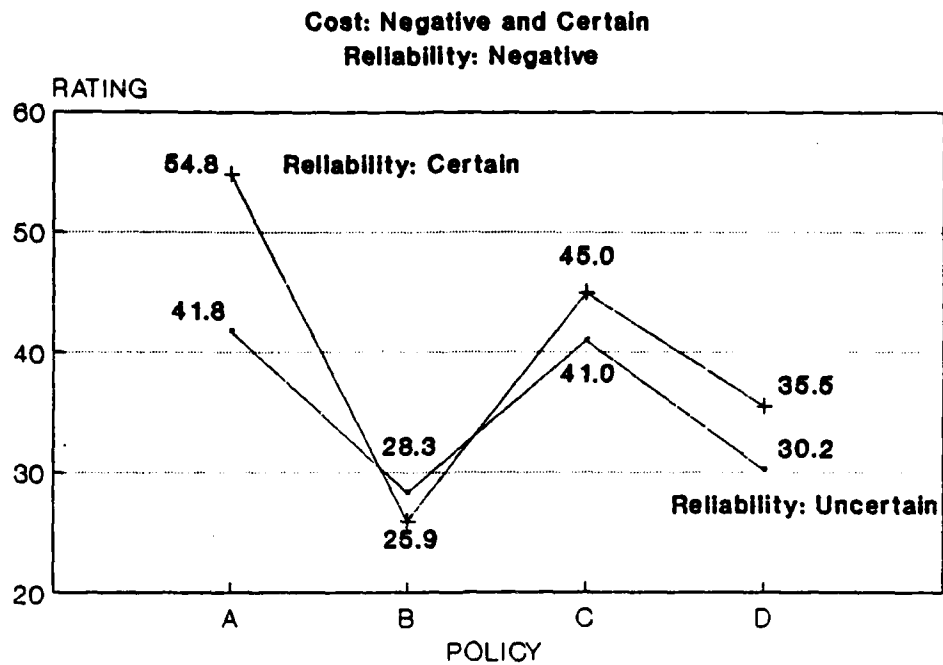


**Figure 3e. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part e)**

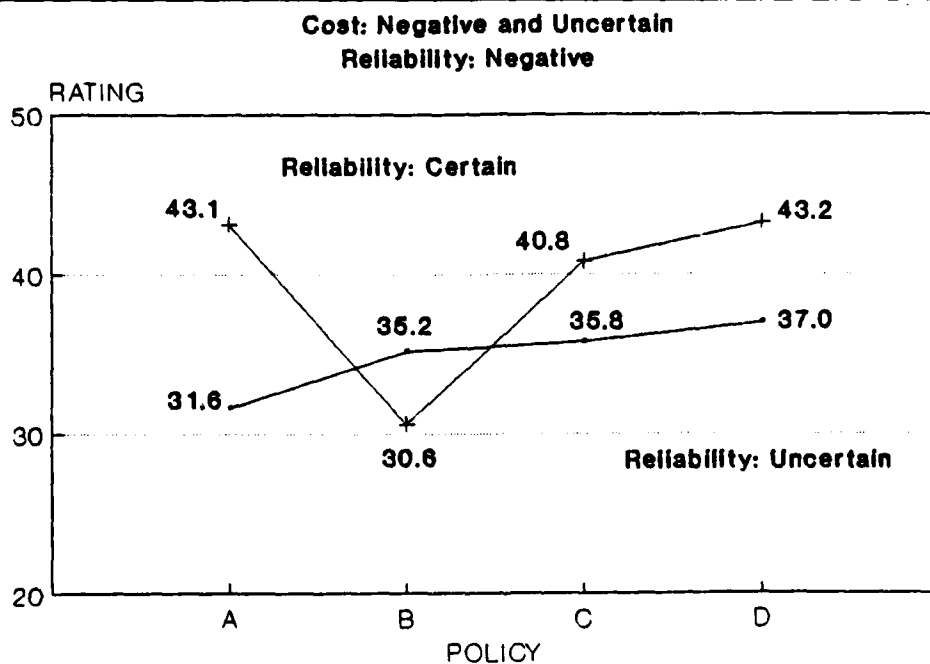


**Figure 3f. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part f)**





**Figure 3g. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part g)**



**Figure 3h. Five-way Interaction: Policy\*Cost\*  
Cost Certainty\*Reliability\*Reliability Certainty (Part h)**

sufficiently large to adversely affect the alternatives' ratings when reliability was uncertain. This indicates, perhaps, that "30%" was not viewed as a "small chance".

A comparison of Figures 3c-3f shows a difference in the way Policy C subjects treated the levels of cost and reliability. The variables in Figures 3c and 3d are the same as in Figures 3e and 3f except cost is positive and reliability is negative in the first two, and they are negative and positive, respectively, in the last two. Policy C (a small chance of not meeting the criteria was allowed) subjects strongly preferred certain reliability over uncertain reliability when cost was negative and reliability was positive (Figures 3e and 3f). This gap, however, narrowed when cost was positive and reliability was negative (Figures 3c and 3d); reliability certainty was rated approximately equal to reliability uncertainty. The allowance for a small level of risk was not applied equally to both variables. The Policy C group was relatively risk-seeking (higher rating for uncertainty) when cost was positive and reliability was negative (Figures 3c and 3d), but risk-averse when the levels of these two variables were reversed (Figures 3e and 3f).

Figures 3g and 3h depict another notable interaction. Policy A test subjects rated reliability certainty disproportionately higher than uncertain reliability regardless of the other within-subject factors. Policy A allowed for no uncertainty and, thus, certain reliability

resulted in higher ratings. The effect of Policy A is noticeable when Policy A is compared to Policy D. Whereas the Policy A values were 43.1 and 31.6 in Figure 3h and 54.8 and 41.8 in Figure 3g, Policy D (control group) values moved in the opposite direction between Figure 3h and Figure 3g. The control group (Policy D) in this case was consistent with prospect theory, preferring uncertain negative cost over certain negative cost (43.2 [Figure 3h] to 35.5 [Figure 3g]). Policy A subjects, however, strongly preferred the certain negative cost (54.5 [Figure 3h] to 43.1 [Figure 3g]).

This last effect becomes a major point in analyzing how policy interacted with the other 4 variables. When cost was negative and reliability was certain and negative, prospect theory correctly predicted a risk-taking posture for Policy B and Policy D; these subjects preferred uncertain cost to certain cost. However, Policy A and C subjects remained risk-averse just as they were when the variables were positive. Some policies, therefore, can apparently change risk-taking tendencies when decision makers are faced with negative outcomes.

Figures 3g and 3h also show an interaction regarding Policy B similar to that already discussed in analyzing Figure 3c. Again, Policy B subjects, focusing on no negative outcomes, preferred uncertain negative reliability over certain negative reliability. This reversal occurred in all instances where reliability was negative except when

cost was positive and uncertain (Figure 3d) and the values in that instance were very similar (46.9 to 45.6). Policy B, in this situation, was the only policy group that conformed to the predictions of prospect theory; the other three groups were more inclined to be risk averse. Thus, Policy B (no negative outcomes allowed) can cause people to become more risk taking even though the intent of the policy is to avoid losses.

Finally, this five-way interaction becomes more significant given the results of the four-way interactions (reference Table 5). Of the five four-way interactions, only one (Policy\*Cost\*Cost Certainty\*Reliability) proved to be a significant interaction. Yet, the presence of all five independent variables did significantly affect the ratings of the alternatives.

Hypothesis 2: Cost and cost certainty will interact to significantly affect the evaluations of logistics alternatives.

The results of this two-factor ANOVA showed that the hypothesized effect did occur ( $p=.0001$ ). The levels of cost (positive and negative) interacted with the levels of cost certainty (certain and uncertain) to affect how the logisticians rated the proposal alternatives. Figure 4 shows this interaction.

Figure 4 shows there was difference in how the subjects rated cost certainty when cost was negative. However, when cost was positive, costs that were certain were rated

significantly higher. In a pairwise comparison of means when cost was positive, cost certainty was rated significantly greater than cost uncertainty with  $p=.0001$ . These results only partially agree with the prospect theory reported by Tversky and Kahneman. Prospect theory predicted a preference for positive certainty but also a preference for negative uncertainty (30:277-288). Instead, the findings of the cost/cost certainty interaction more closely agree with those by Emmelhainz. In his research, when analyzing cost and customer service variables, positive certainty was preferred over positive uncertainty but no significant difference existed when the variables were negative (19:236).

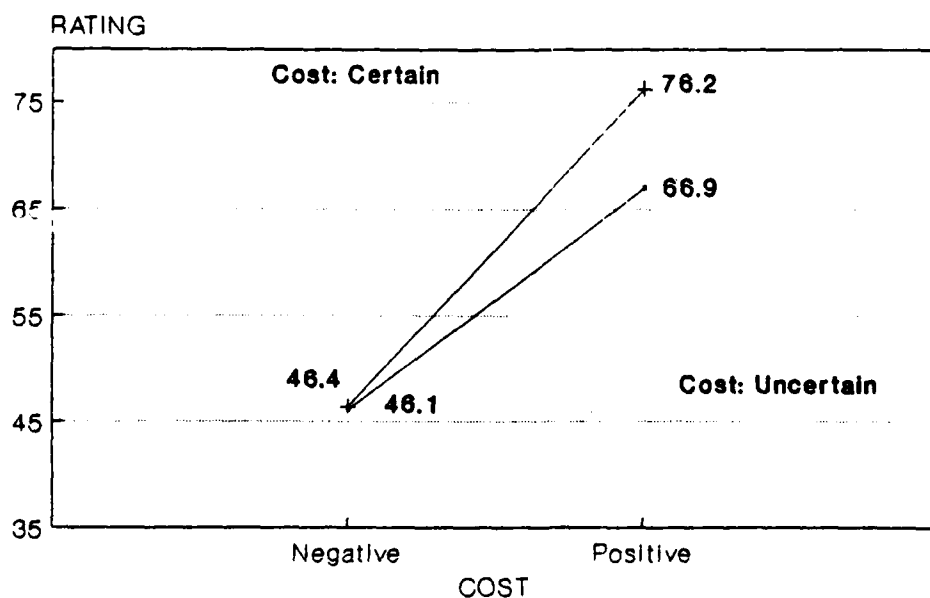


Figure 4. Two-way Interaction:  
Cost\*Cost Certainty

It has already been shown in the analysis of the five-way interaction that this two-way interaction is more accurately the result of the significant differences that were shown by the five-factor analysis. These lower order interactions, however, do show some general trends in the decisions made by the logisticians.

Hypothesis 3: Reliability and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

The results of this two-way ANOVA also showed that the hypothesized effect did occur ( $p=.0001$ ). The levels of reliability significantly interacted with the levels of reliability certainty to affect how the logisticians rated the proposal alternatives. Figure 5 depicts this interaction.

These results are strikingly similar to the manner in which cost and cost certainty were treated. Again, certain positive reliability was rated significantly higher ( $p=.0001$  in a comparison of the two means) than uncertain positive reliability but little difference occurred when reliability was negative. Predictions of prospect theory were again only partially fulfilled. As with Hypothesis 2, the reasons for these values are more fully explained in the analysis of the five-way interaction.

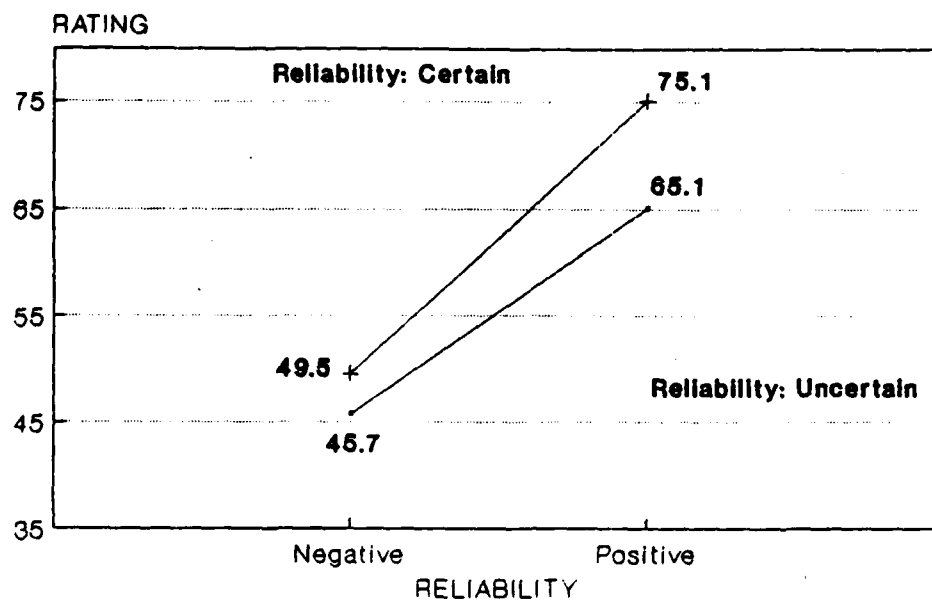


Figure 5. Two-way Interaction:  
Reliability\*Reliability Certainty

Hypothesis 4: Policy and cost certainty will interact to significantly affect the evaluation of logistics alternatives.

The results of this two-way ANOVA showed that the four levels of policy interacted with the two levels of cost certainty to significantly affect the ratings of the proposal alternatives ( $p=.0078$ ). Table 5 shows that cost certainty alone was significant in evaluating the alternatives; however, the two-way interaction with policy shows there was a strong relationship between the way cost certainty was viewed and the policy the test subjects were given. Figure 6 depicts this interaction.

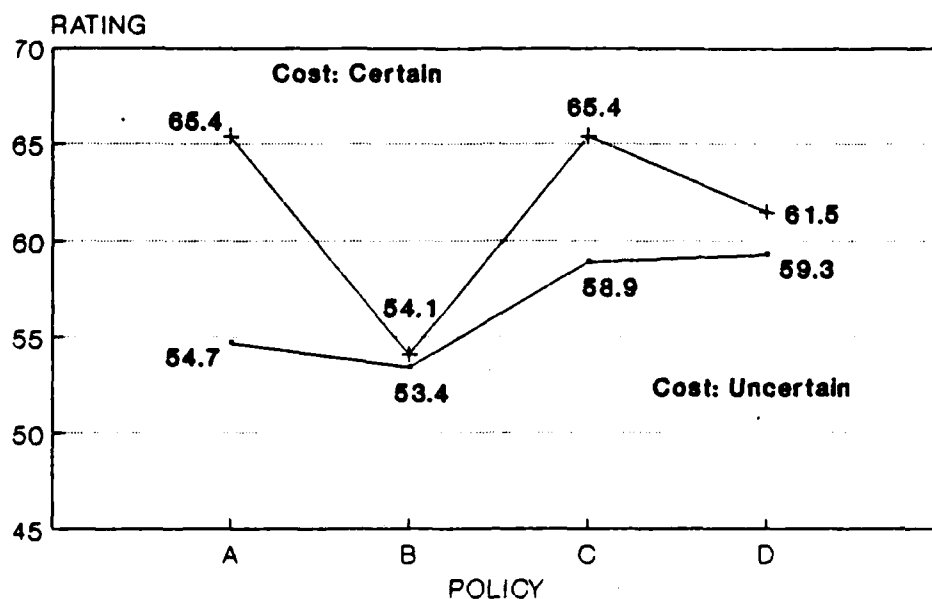


Figure 6. Two-way Interaction:  
Policy\*Cost Certainty

The significant differences occurred primarily with Policy A and Policy C. The control group, Policy D, rated the two choices nearly equally. Policy B (no negative outcomes) subjects also rated them equally despite the uncertain cost having a chance for a loss. However, the Policy A group clearly focused on the uncertainty and rated cost uncertainty considerably lower. Policy C allowed for a small chance of a negative outcome; the cause of the interaction with Policy C can only be speculated in this context but it may be that cost certainty was significantly interacting with Policy C when other variables were at certain levels. This can be verified by analyzing higher order interactions containing both policy and cost



certainty. The analysis of Hypothesis 6 will examine such a case.

Hypothesis 5: Policy and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

The results of this two-way ANOVA showed that the four levels of policy interacted with the two levels of reliability certainty to significantly affect how the logisticians rated the proposal alternatives ( $p=.0027$ ). Again, the policy the subjects were guided by interacted with whether reliability was certain or uncertain to affect their evaluations of the decision alternatives. Figure 7 depicts this interaction.

The differences in this case appeared strongest under guidance from Policy A and Policy B. Understandably, subjects who were told not to allow any uncertainty (Policy A) rated uncertain reliability lower than the control group and certain reliability higher than the control group. This result was similar to the interaction between policy and cost certainty shown in Figure 6.

Test subjects who were given guidance to allow for no negative outcomes (Policy B) rated reliability certainty proportionately lower than reliability uncertainty compared to any of the other three policy groups. The cause for this difference may have been due to low ratings for negative, certain reliability compared to negative, uncertain reliability (containing a chance of a positive outcome).

This interaction is further analyzed in the results of Hypothesis 7.

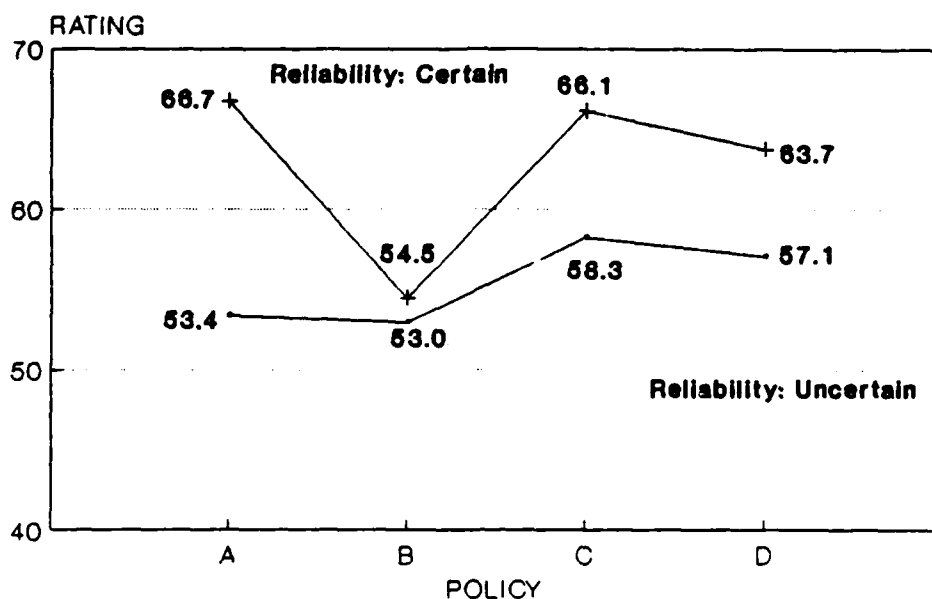


Figure 7. Two-way Interaction:  
Reliability\*Reliability Certainty

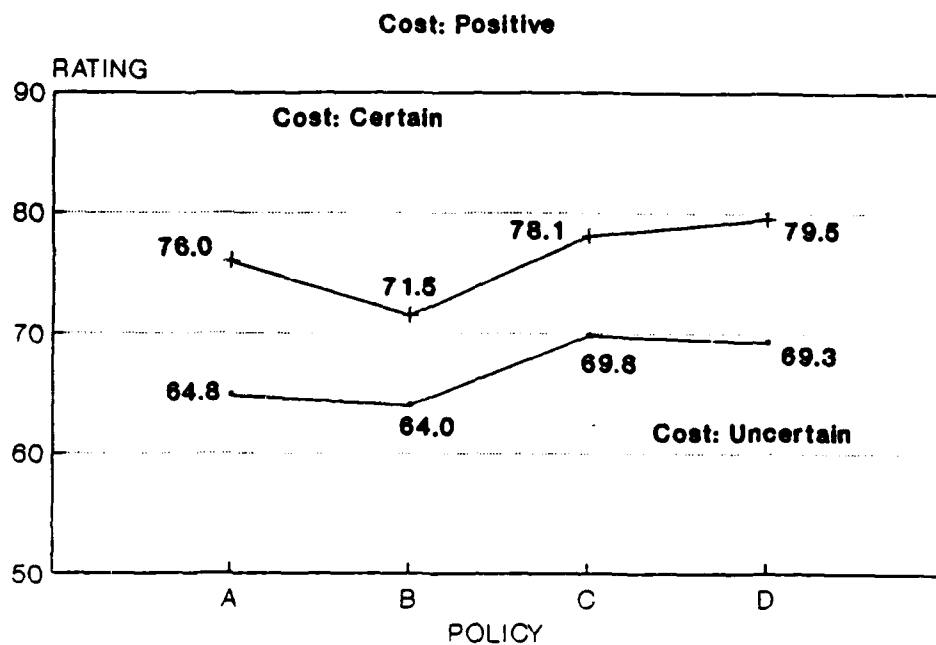
Figures 6 and 7 present an interesting contrast between how cost certainty and reliability certainty were treated. The plots are similar in most respects, except, perhaps, for the manner in which the control group (Policy D) treated the two factors. To them, certain reliability was a relatively more important influence on the ratings than certain costs. This suggests that logistics decision makers who have no guiding risk policies will treat reliability data presented in terms of certainty more favorably than cost data presented in terms of certainty; or, perhaps, that logistics decision

makers who are not explicitly focusing on risk, may be less affected by uncertain costs than uncertain reliability.

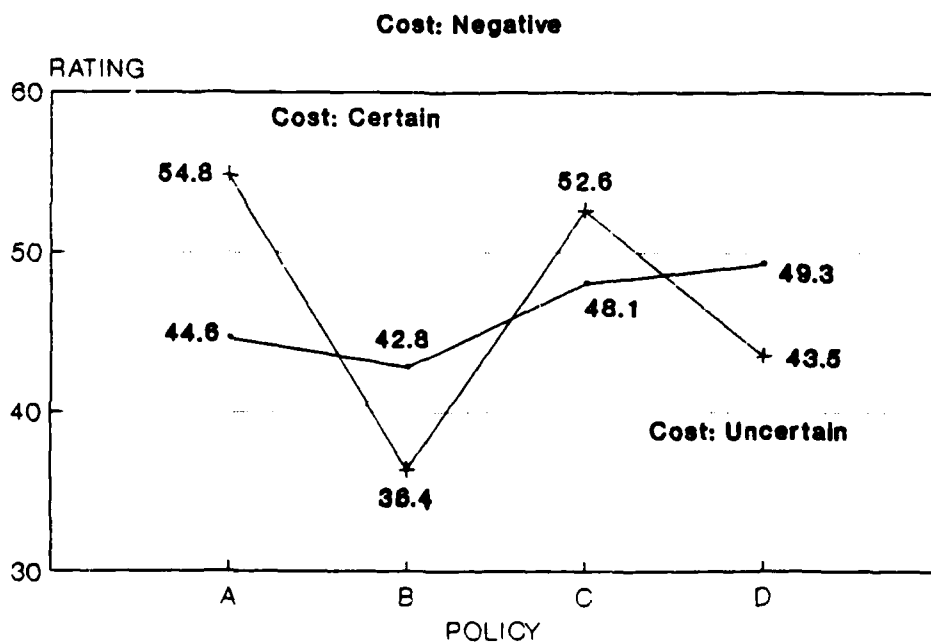
Hypothesis 6: Policy, cost, and cost certainty will interact to significantly affect the evaluations of logistics alternatives.

The results of this three-way interaction showed that the four levels of policy interacted with the two levels each of cost and cost certainty to significantly affect how the logisticians rated the proposal alternatives ( $p=.0058$ ). Figures 8a and 8b show that this interaction was most evident when cost was negative.

When cost was positive, certainty and uncertainty were treated nearly uniformly across all policies (approximately parallel lines). However, the interaction between the three variables was evident when cost was negative. When cost was negative (Figure 8b), two groups showed a preference for uncertain cost. First, the control group (Policy D) mirrored the predictions of prospect theory and preferred uncertain negative cost to certain negative cost. This illustrates a risk-seeking posture when cost was negative. Second, the Policy B subjects also preferred a risk-seeking course of action. This was expected since a certain loss was counter to their guiding policy which allowed for no negative outcomes.



**Figure 8a. Three-way Interaction:  
Policy\*Cost\*Cost Certainty (Part a)**



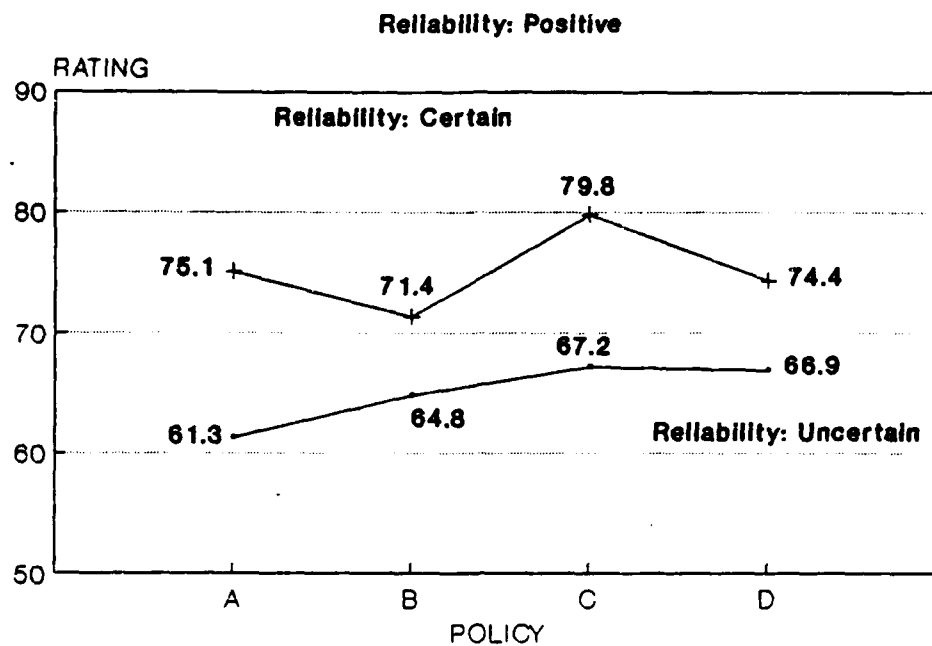
**Figure 8b. Three-way Interaction:  
Policy\*Cost\*Cost Certainty (Part b)**

Policies A and C remained risk averse. Since Policy A allowed no uncertainty, it is clear why that group rated certainty higher than uncertainty. In the case of Policy C, it seems that advising people that a small chance of a negative outcome is allowed, also makes people less risk seeking with negative numbers, although not as much as with Policy A. This is yet another example of policy controlling the actions predicted by prospect theory. Both Policy A and Policy C cause risk to be less attractive.

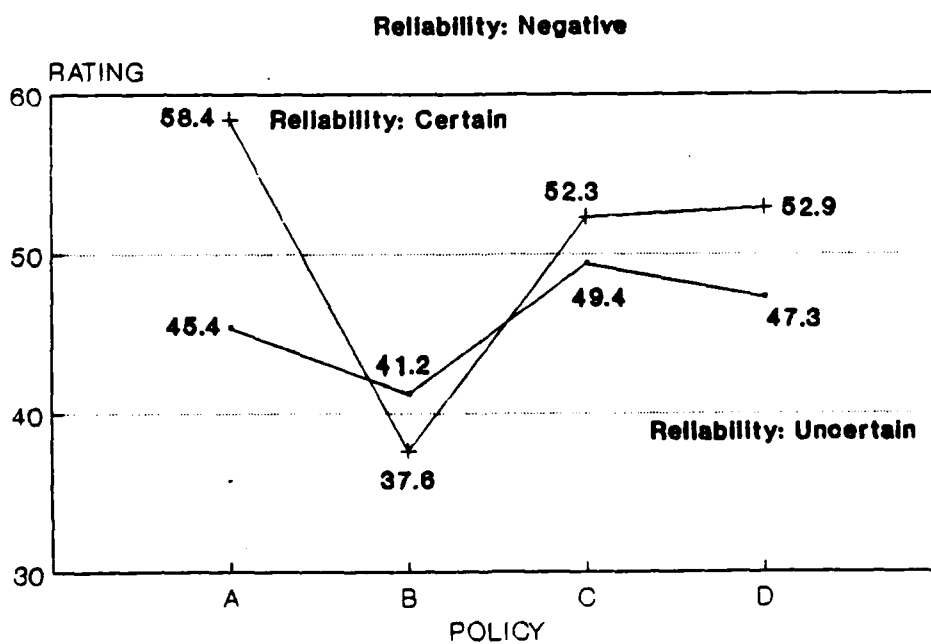
Hypothesis 7: Policy, reliability, and reliability certainty will interact to significantly affect the evaluations of logistics alternatives.

The results of this three-way ANOVA showed that the four levels of policy interacted with the two levels each of reliability and reliability certainty to significantly affect how the logisticians rated the proposal alternatives ( $p=.0301$ ). Figures 9a and 9b depict this interaction.

Similar to the policy/cost/cost certainty interaction, policy had little influence when reliability was positive. The plot comparing uncertainty with certainty (Figure 9a) shows nearly parallel lines. Again, the interaction was evident when reliability was presented as a negative outcome. In this case, however, the control group (Policy D) preferred certain, negative reliability to uncertain, negative reliability. Whereas this group was risk seeking when cost was negative (Figure 8b), they were less apt to take a risk when reliability was negative even though there was a chance



**Figure 9a. Three-way Interaction:  
Policy\*Reliability\*Reliability Certainty (Part a)**



**Figure 9b. Three-way Interaction:  
Policy\*Reliability\*Reliability Certainty (Part b)**

of a better outcome (20% chance of .93 and 10% chance of .98). Hence, prospect theory was rejected by the control group when reliability was negative. Perhaps the 70% chance that reliability rates would be as low as 82% or 86% was unacceptable and a certain reliability of 87% was preferred. The negative consequences and the higher probabilities of the risky (uncertain) alternatives were too great for this group.

As was the case with cost/cost certainty, the Policy B group (no negative outcomes allowed) preferred the negative, uncertain reliability over negative, certain reliability. This showed that Policy B influenced their ratings in a similar manner irrespective of which dimension of the alternative was potentially a negative outcome. This similar treatment of cost and reliability was not evident in the responses from the control group (Policy D). Comparing the values in Figure 8b with Figure 9b, the control group rated negative, uncertain cost and negative, uncertain reliability nearly equal (49.3 and 47.3, respectively). However, a significant difference existed in their treatment of cost and reliability when these two variables were negative and certain (43.5 [Figure 8b] and 52.9 [Figure 9b]).

#### Other Significant Interactions

Each of the within-subject main effects (cost, cost certainty, reliability, and reliability certainty) significantly affected the ratings of the decision alternatives. Naturally, positive cost (a gain) was

preferred over negative cost (a loss), and positive reliability was preferred over negative reliability. Similarly, cost certainty was preferred over cost uncertainty, and reliability certainty was preferred over reliability uncertainty. These effects were anticipated and confirm that the experiment worked.

The between-subject main effect (policy) did not significantly affect the ratings. Since policy did significantly interact with the other variables in seven combinations, the absence of its main effect can be interpreted two ways. First, the range of ratings within each was great enough to generate large standard deviations. Large standard deviations make it difficult to distinguish a difference between sample means. Second, the policies used probably affected positive alternatives in one way and negative alternatives in the opposite manner; or, certain alternatives in one way and uncertain alternatives just the opposite. The effect within each policy group then probably offset. The earlier analyses of the significant interactions confirm these effects.

Interestingly, policy interacted with cost certainty (Figure 4) and reliability certainty (Figure 5) but did not significantly interact with either cost or reliability (with  $\alpha=.05$ ). This suggests that the policies were interpreted in a manner such that the test subjects were focusing primarily on the probabilities and secondarily on the consequences. Even the effect of Policy B (no negative

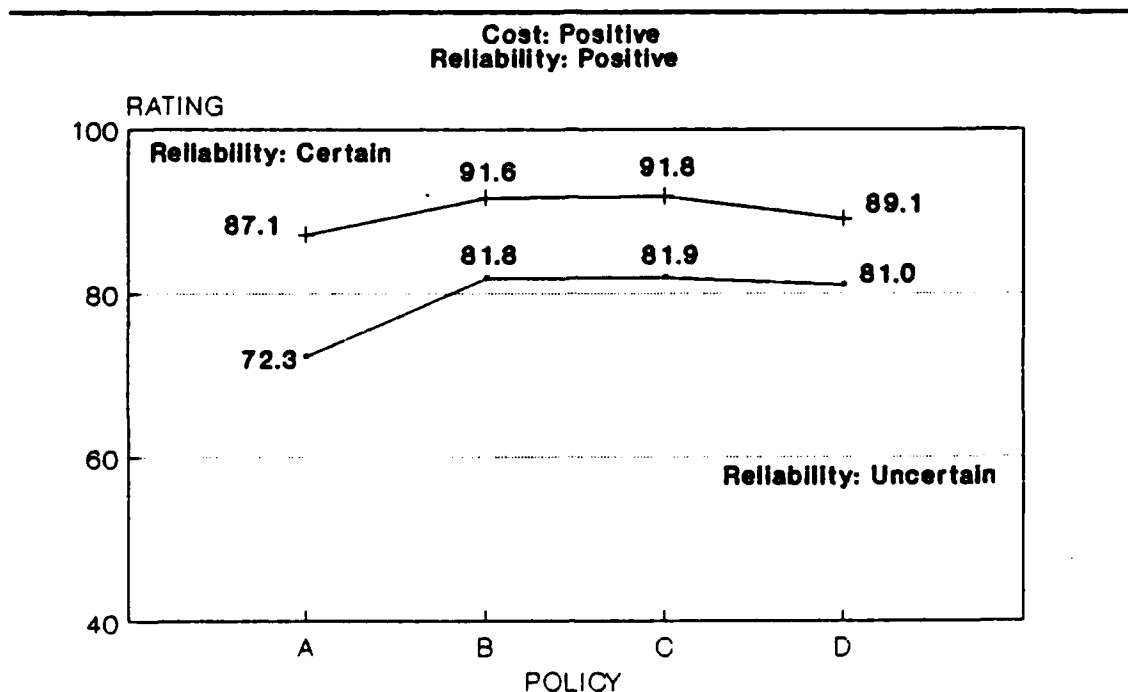


outcomes) was only manifested in higher order interactions with the cost or reliability variables.

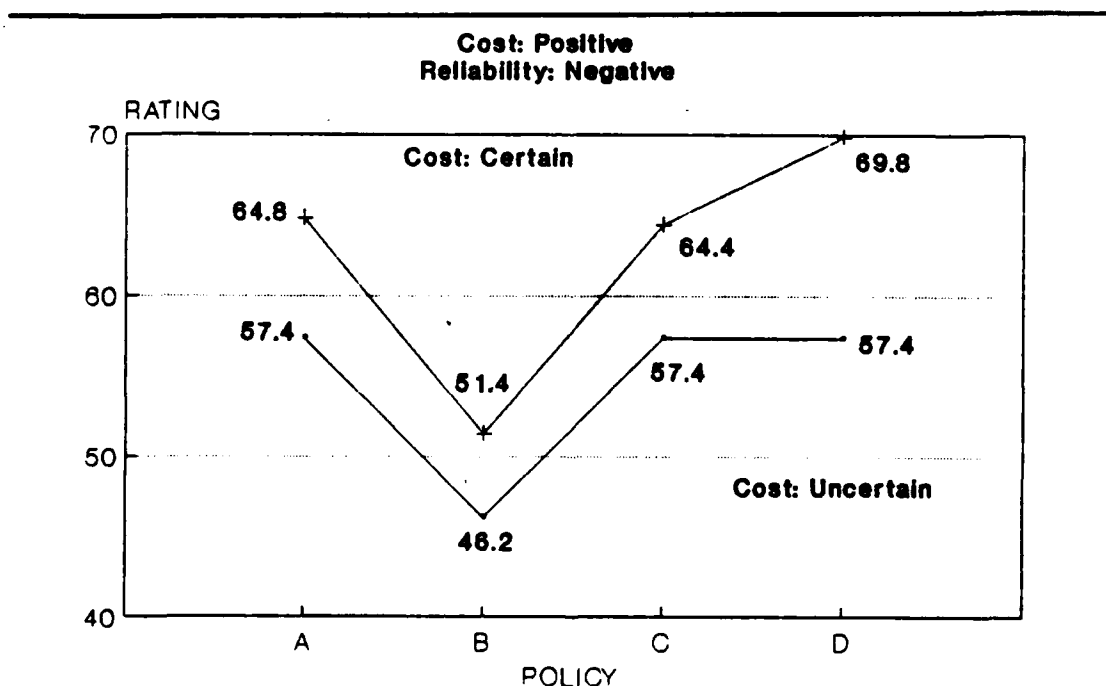
One higher order interaction that was not anticipated was a significant effect ( $p=.0097$ ) from policy interacting with cost, cost certainty, and reliability. Figures 10a-10d depict this four-way interaction.

Clearly, there was a significant difference in the way cost certainty was evaluated when cost was positive (Figures 10a and 10b) as opposed to when cost was negative (Figures 10c and 10d). When cost was positive, cost certainty was consistently and proportionately preferred to cost uncertainty regardless of the level of reliability. However, when cost was negative, Policy B and Policy D test groups assumed a risk-seeking posture. On the other hand, Policy A and Policy C caused risk aversion in their respective test groups.

These effects were actually seen more clearly in the five-way interaction discussed earlier. In fact, Figure 10c is a combined summary of Figures 3e and 3f (from the five-way analysis), and Figure 10d is a summary of Figures 3g and 3h. What is not seen in the four-way analysis is that, even though the four-way interaction was significant, the fifth independent variable (reliability certainty) was also influencing the ratings within this interaction.



**Figure 10a. Four-way Interaction: Policy\*  
Cost\*Cost Certainty\*Reliability (Part a)**



**Figure 10b. Four-way Interaction: Policy\*  
Cost\*Cost Certainty\*Reliability (Part b)**

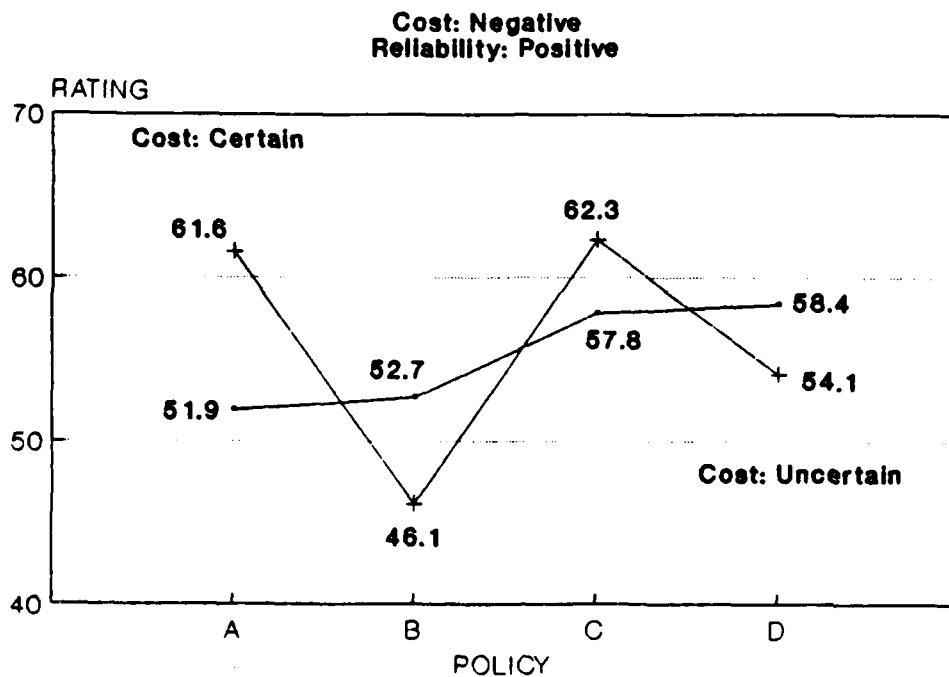


Figure 10c. Four-way Interaction: Policy\*  
Cost\*Cost Certainty\*Reliability (Part c)

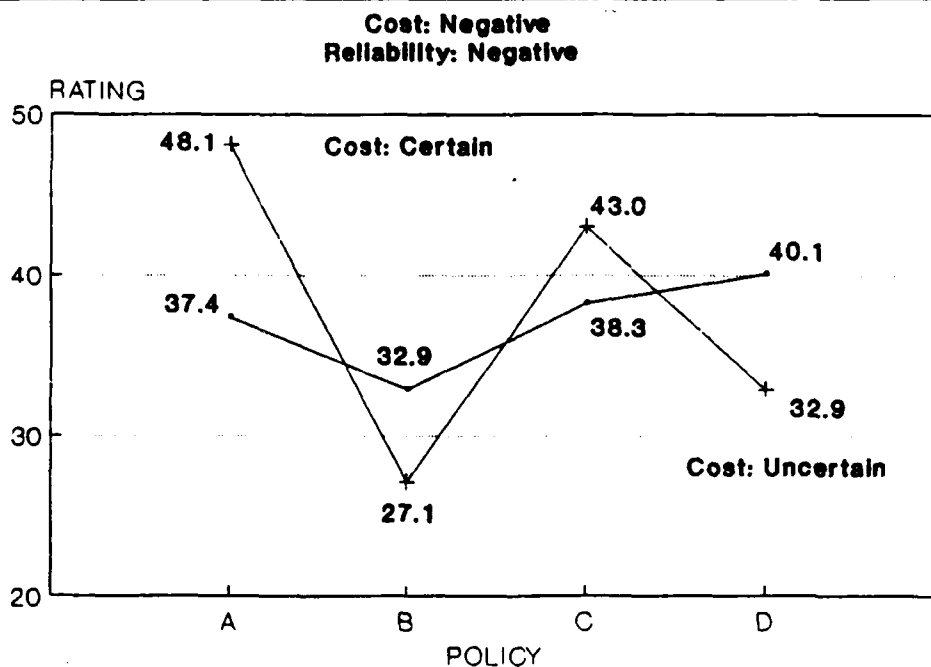


Figure 10d. Four-way Interaction: Policy\*  
Cost\*Cost Certainty\*Reliability (Part d)

### Expected Cost and Expected Reliability Dependent Variables

An analysis of variance was also performed on the responses for both the expected cost of the system and expected reliability of the system for all combinations of the independent variables. Logically, only the level of the cost variable or the level of the reliability variable would have affected the expected cost or expected reliability, respectively. The reasoning was that the level of cost, for instance, did, in fact, determine the statistically correct expected cost. However, the other independent variables, or any combination of them, should not have affected either the expected cost or the expected reliability. This held true for the cost dimension. Only the main effect, cost, significantly affected the expected cost response. Thus, whereas risk influenced the ratings in many complex ways, the costs were evaluated irrespective of risk.

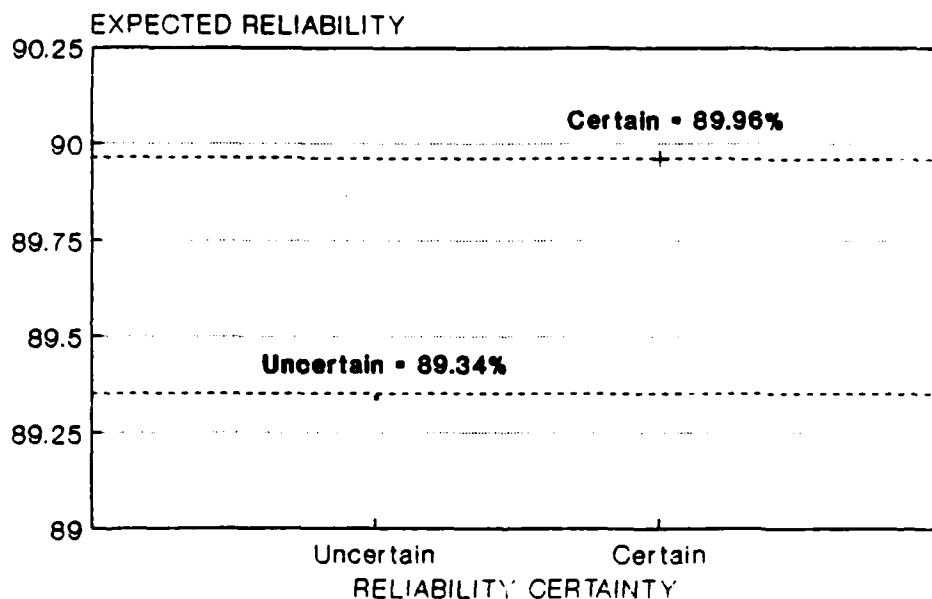
The expected reliability response, however, was significantly affected ( $\alpha=.05$ ) by the main effect, reliability, as well as by one other main effect and by two higher order interactions. Table 6 lists the interactions which significantly affected the expected reliability rates for the evaluated alternatives.

The fact that reliability certainty influenced the evaluation of the expected reliability rate is shown in Figure 11. Since there were an equal number of alternatives having a "statistically correct" value of 93%

**Table 6. Significant Interactions  
on the Dependent Variable "Expected Reliability"**

<u>Source of Variance</u>	<u>F-value</u>	<u>Tail Probability</u>
Reliability Certainty (RC)	8.94	.0036
Cost*Reliability*Policy	2.94	.0374
Cost*RC*Reliability*Policy	3.19	.0274

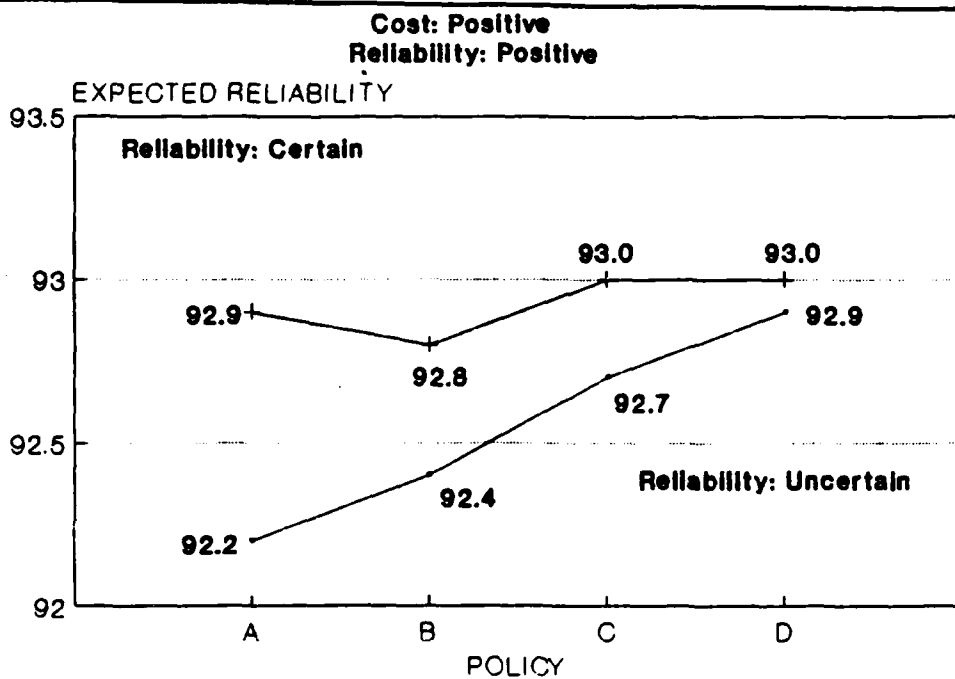
as there were having 87%, the average expected reliability for all the alternatives should have been 90%. Reliability stated in certain terms were accurately expected to perform at 89.96% by the test subjects. However, uncertain reliability data were assessed to produce an 89.34% reliability rate. Hence, test subjects were pessimistic when reliability data were presented in uncertain terms.



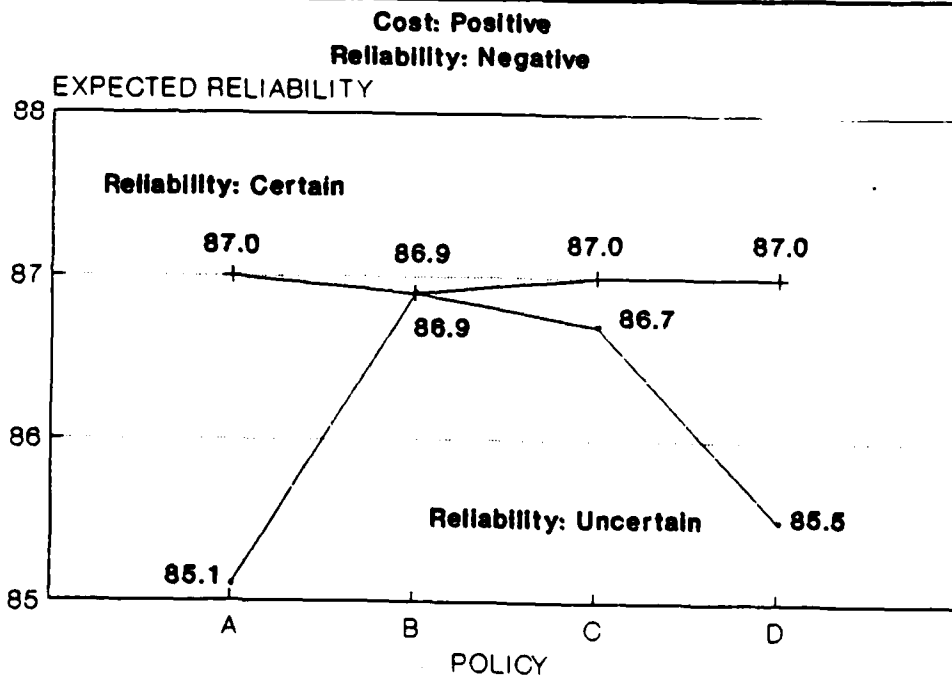
**Figure 11. Main Effect: Reliability  
Certainty on Expected Reliability**

Analysis of the significant four-way interaction (Policy\*Cost\*Reliability\*Reliability Certainty shown in Figures 12a-12d) on the expected reliability showed that the main effect of uncertain reliability data was again manifested. Generally uncertain reliability was assessed as producing lower reliability rates than data presented in certain terms (although they were statistically equal in terms of mathematical expected value). This was especially true when both cost and reliability were negative as judged by Policy A subjects. Under these conditions, they assessed certain reliability as providing an 87.0% reliability rate (statistically correct) as opposed to an 85.0% reliability rate for the uncertain systems.

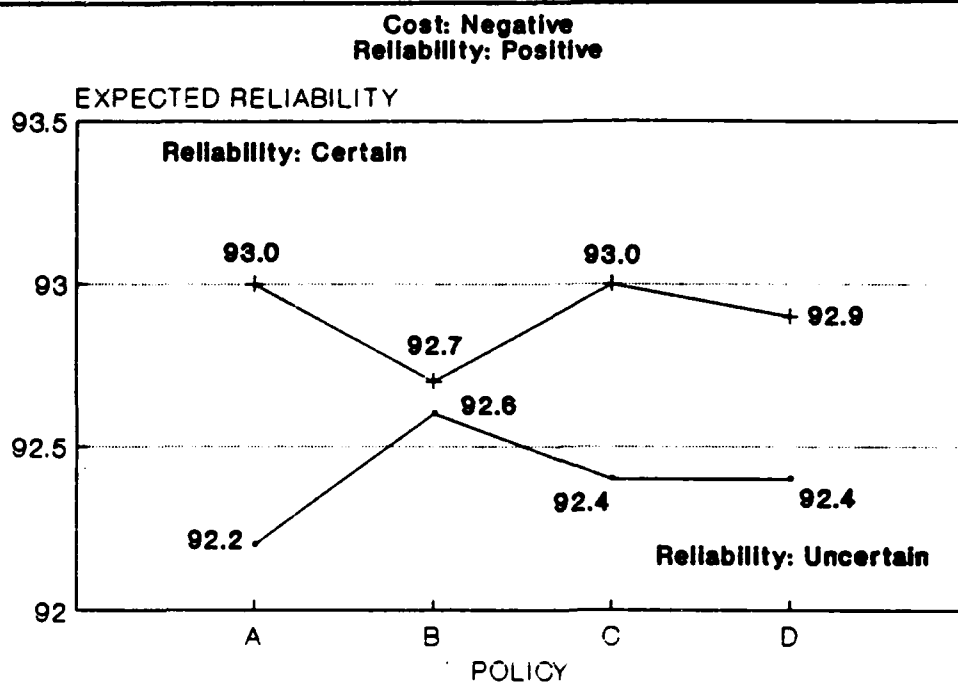
In contrast, Policy B subjects (no negative outcomes guidance), assessed the expected reliability rates with uncertain data to be slightly higher (87.0% compared to 86.9%) than the alternatives with reliability rates stated in certain terms, when reliability was negative. This suggests, perhaps, that since no negative outcomes were allowed, they focused on the positive outcomes and assessed the expected reliability accordingly. Because the rank orders required different statistical tests, time precluded analysis on the ordinal data using the rank order of the alternatives as the dependent value.



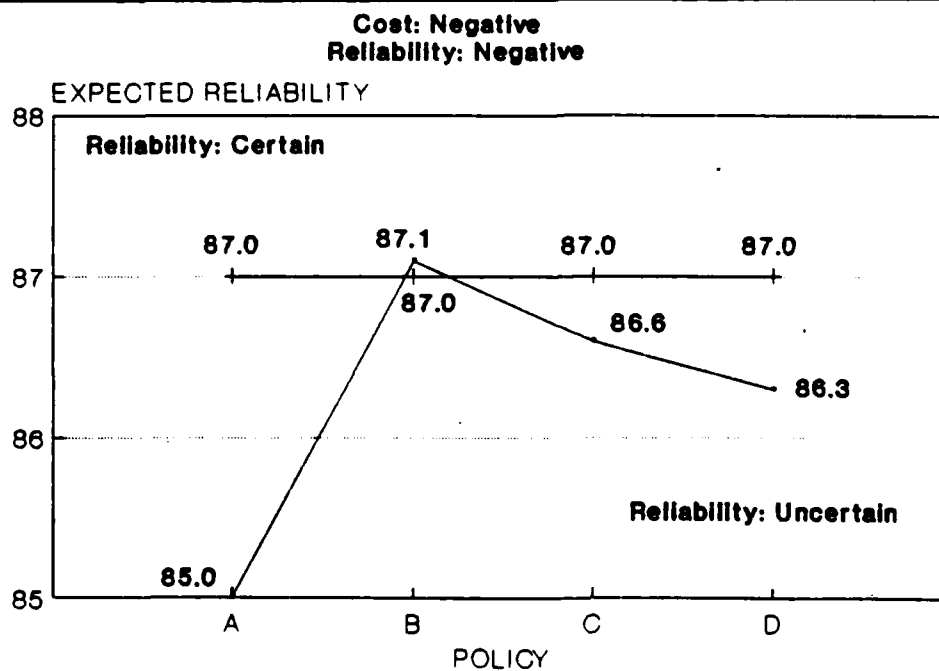
**Figure 12a. Four-way Interaction: Policy\*Cost\*Reliability\*Reliability Certainty on Expected Reliability (Part a)**



**Figure 12b. Four-way Interaction: Policy\*Cost\*Reliability\*Reliability Certainty on Expected Reliability (Part b)**



**Figure 12c. Four-way Interaction: Policy\*Cost\*Reliability\*  
Reliability Certainty on Expected Reliability (Part c)**



**Figure 12d. Four-way Interaction: Policy\*Cost\*Reliability\*  
Reliability Certainty on Expected Reliability (Part d)**



### Questionnaire Responses

Appendix D contains a complete summary of all the responses to the experiment's questionnaire. The responses to several of the questions warrant some discussion.

Generally, the test subjects believed the alternatives were realistic (72.5% replied strongly agree, agree, or agree slightly) and were representative of decisions an organization might make (71.8% in agreement). The respondents felt that both cost and reliability were important in making purchasing decisions. Eighty-five percent felt cost was an important consideration and ninety-six percent believed reliability was an important consideration. Finally, 59% of the respondents agreed that reliability was more important than cost, 29% felt cost was more important, and 12% thought they were equally important.

Thirty-five percent of the test subjects previously occupied a managerial position in a logistics capacity. The remaining 65 percent were either logistics specialists or logistics students. The average age of all respondents was 33.1 years old (PCE students: 34.1 years old; AFIT graduate students: 30.1 years old).

The responses to Question 18 through Question 23 give a general indication of the risk attitudes of the test subjects. These questions were also used by Kahneman and Tversky (30:268) and by Emmelhainz (19:219-221). They offer a means of comparing the risk propensities of the test

subjects. Tables 7a-7b compare the responses from this thesis to the other two studies.

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Table 7a. Comparison of Questionnaire Responses  
To Other Studies (Part a)

Alternatives	This <u>Thesis</u>	<sup>**</sup> <u>Emmelhainz</u>	<sup>*</sup> <u>K&amp;T</u>
Question 18:			
a. An 80% chance of gaining \$4,000 and a 20% chance of gaining \$0.	18.5%	37.5%	20%
b. A certain gain of \$3,000.	81.5%	62.5%	80%
Question 20:			
a. An 80% chance of losing \$4,000 and a 20% chance of losing \$0.	67.6%	75.7%	92%
b. A certain loss of \$3,000.	32.4%	24.3%	8%
Question 19:			
a. A 25% chance of gaining \$3,000 and a 75% chance of gaining \$0.	58.4%	50.7%	35%
b. A 20% chance of gaining \$4,000 and an 80% chance of gaining \$0.	41.6%	49.3%	65%
Question 21:			
a. A 25% chance of losing \$3,000 and a 75% chance of losing \$0.	58.4%	62.9%	58%
b. A 20% chance of losing \$4,000 and an 80% chance of losing \$0.	41.6%	37.1%	42%

\* Kahneman and Tversky

\*\* Data for responses to studies by Emmelhainz and by  
Kahneman and Tversky taken from Emmelhainz (EM:219-221)

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Table 7b. Comparison of Questionnaire Responses  
To Other Studies (Part b)

Question 22:	<u>This Thesis</u>	<u>Emmelhainz</u>	<u>K&amp;T</u>
a. A 90% chance of gaining \$3,000 and a 10% chance of gaining \$0.	82.4%	90.3%	86%
b. A 45% chance of gaining \$6,000 and a 55% chance of gaining \$0.	17.6%	9.7%	14%
Question 23:			
a. A 90% chance of losing \$3,000 and a 10% chance of losing \$0.	24.1%	29.2%	8%
b. A 45% chance of losing \$6,000 and a 55% chance of losing \$0.	75.9%	70.8%	92%

Equivalence between the four test groups was achieved by random assignment to each policy. Although the split-plot design relaxes the homogeneity and sphericity assumptions, the ability to aggregate the findings of other research with this study will be based on the study groups' equivalence in terms of risk-taking propensities. Table 8 depicts each groups' responses to Questions 18-23 and compares them again to the studies by Kahneman and Tversky and by Emmelhainz. Caution should be exercised in making any comparison between the responses beyond a visual comparison. Although the test subjects were asked to give their personal responses to the questions, some carryover from the risk policies they were given may have occurred. Consequently, their perceptions of the risks and responses

to the questions may have been influenced by the test group they were in.

Table 8. Comparison of Questionnaire Responses  
Between Policy Groups (Questions 18-23)

<u>Question</u>	<u>Answer</u>	<u>Policy: A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>Emmelhainz</u>	<u>K&amp;T</u>
18	a	8%	21%	31%	14%	37%	20%
	b	92%	79%	69%	86%	63%	80%
20	a	67%	82%	50%	61%	76%	92%
	b	23%	18%	50%	39%	24%	8%
19	a	67%	50%	65%	43%	51%	35%
	b	33%	50%	35%	57%	49%	65%
21	a	50%	57%	69%	57%	63%	58%
	b	50%	43%	31%	43%	37%	42%
22	a	92%	75%	82%	82%	90%	86%
	b	8%	25%	18%	18%	10%	14%
23	a	23%	29%	18%	25%	29%	8%
	b	77%	71%	82%	75%	71%	92%

### Summary

Fifteen combinations of the five independent variables were shown to significantly interact to affect the logistics decision in this thesis' experiment. Of central importance, the policy variable was present in seven significant interactions. Additionally, each of the seven hypothesized effects did occur. Relevant conclusions from these results are discussed in Chapter V.

## V. Conclusions and Recommendations

This chapter presents a brief summary of the thesis objective and the methodology used to pursue that objective. It follows with conclusions to the three specific research questions and pertinent comments about the experiment's hypotheses. This chapter then discusses the overall conclusions drawn from the research and the relevant implications to logistics managers. It concludes with recommendations for logistics managers and presents ideas concerning future research efforts.

### Summary of the Research

The primary intent of this thesis was to determine whether management policies can influence how logistics managers make decisions involving risk and uncertainty. While it is widely recognized that people respond in certain ways to risk inherent decisions, very little research has focused on influencing the way people react when faced with risk. An organization's ability to establish risk guidance, and to predict how this will affect its employees' decision making, would provide substantial benefits. This is shown to be especially cogent in the field of logistics where the necessity for basing important decisions on speculative data is manifested in several areas.

To achieve this objective, an experimental situation was used involving a logistics decision to purchase a needed computer system for the test subjects' respective organizations. The decision was based on cost and reliability data about 16 separate proposal alternatives, each of which contained varying degrees of risk and uncertainty. Risk policy in the form of supervisor's guidance was given to three test groups. The first group (Policy A) was told not to allow for any uncertainty, thereby eliminating a necessary condition for risk. Management strongly preferred to know beforehand the exact cost and reliability of the system it was purchasing. The second group (Policy B) was told not to allow for any negative consequences. This policy focused on the other necessary condition for risk: the potential for a loss. The third group (Policy C) was told that a small chance of a loss was permissible. This focused their attention on both the probabilities of the outcomes and the potential consequences. The wording, a small chance, was purposely vague. Finally, the fourth group (Policy D) was given no guidance concerning risk and represented the control group.

The responses to the thesis experiment were analyzed using an ANOVA procedure with a split-plot repeated measures design. All combinations involving the between-subjects factor (policy) and the within-subject factors (cost, cost certainty, reliability, and reliability certainty) were

analyzed to detect any interactions which significantly affected how the logistics decisions were made.

### Conclusions Related to the Research Questions

**Research Question 1: Can an organization establish policies addressing risk that change the way managers assess risk-inherent decisions?**

Organizations can establish policies which address risk that significantly influence the manner in which their managers assess risk-inherent decisions. These risk policies in many cases contribute to producing a distinct and predictable influence on how logistics managers will respond to perceptions of risk. However, a risk policy by itself may be insufficient to explain why there is a change in the way risk is considered by decision makers. This was shown by the absence of a main effect from the policy variable in this thesis research. More likely, a policy will work in concert with other variables to influence the way risk is assessed. This concept is explained in more detail later in this chapter.

**Research Question 2: Do the presence of risk and uncertainty affect the way logistics managers make decisions?**

Logistics managers are definitely affected by the presence or absence of risk in a logistics decision. The presence of risk will change the way logistics decisions are made. The predictions of prospect theory (30:277-288), however, tend to oversimplify the responses to inherently

complex logistics decisions. Generally, prospect theory accurately predicts a risk averse response from logistics decision makers who are faced with positive outcomes. On the other hand, logistics decisions which will likely result in negative outcomes are not consistently made in a risk-seeking manner as prospect theory purports. Instead, this research found that evidence was inconclusive about how logisticians respond to risky decisions which have a high probability of resulting in a negative outcome.

Generalizations about how risk affects decisions which will likely result in a negative outcome are impossible to make without considering the complex interactions among other decision variables. The findings of Emmelhainz (19) showed that this was also true in other logistics decisions involving other decision variables.

Research Question 3: Do significant interactions exist between various levels of cost, cost certainty, reliability, reliability certainty, and risk policies when making decisions concerning logistics issues?

Logistics managers are significantly influenced by interactions between cost, cost certainty, reliability, reliability certainty, and policies addressing risk. Each of these variables, as well as interactions between the variables, influenced the decisions made by the logistics managers in this study. The fact that the five-way effect was significant demonstrates the enormous complexities which logistics decisions must address. As analyzed in detail in



Chapter IV, the complexity comes not only from the multitude of decision variables involved, but also from the intricate interactions that occur between the levels of the various variables. An understanding of these interactions, and more importantly, an understanding of how risk policies contribute to these interactions, can have profound implications for logistics organizations. The next section discusses the major conclusions drawn from the research and the specific implications of the findings related to the risk policies.

#### Conclusions Drawn from the Research

(1) The principal conclusion from this research is that policies which address risk that are presented to logistics decision makers will affect the way they make risk-inherent decisions. Other research has shown that people respond in certain ways to decisions involving varying degrees of risk. This research has begun to show that these risk-inherent decisions can be purposely influenced by policies which address risk. While this idea may seem obvious, the research showed that not all policies will make a difference under all conditions. The influences are more predictable with some policies than with others, and they may only be manifested in certain decision situations regardless of the risk policy that is presented. Conclusions and implications about the three specific risk

policies used in this research can be made and are presented in the ensuing discussions.

(2) A policy which permits no uncertainty appears to be easily understood, easy to follow, and generally adhered to in making logistics decisions. This research showed that this type of policy was universally applied to both cost and reliability variables. Whether such a policy is appropriate for a logistics organization was not explored. Certainly, a policy which promotes basing decisions on the absolute predictability of the results would be inappropriate in organizations such as Research and Development where creativity and initiative might thereby be suppressed. This policy becomes inappropriate despite the fact that the policy would provide the organization with predictable behavior from its managers and employees. However, an organization which, for example, is fundamentally dependent on knowing the exact costs or the exact consequences (perhaps, health services) of its managers' decisions can, in fact, influence the decisions in this direction by establishing an explicit policy which does not permit risk taking.

(3) A policy which allows for no negative outcomes may only cause a predictable response for certain decision variables and may result in higher levels of risk taking. For example, in this research when reliability was negative, policy guidance forbidding negative outcomes significantly promoted risk-taking responses. Perhaps this was because

reliability is currently a popular issue in the Department of Defense and in the Air Force (11). It appeared that the test subjects who were told to accept no negative outcomes were primarily focusing on negative reliability. Thus, when reliability was negative, this group consistently assumed a more risk-seeking posture preferring uncertainty over certainty because it presented some chance for gaining a more reliable system.

The cost variable, however, did not interact with this policy in the same manner. The consequences of excess cost may not have been as real or important as was reliability. The implication then is that a policy which stringently rejects negative outcomes will likely be applied to the current organizational emphasis but, perhaps, not as strongly to negative consequences which are less valued.

This idea could have profound logistics implications. For example, if safety is an emphasis item in an organization, managers given this policy might choose a riskier course of action (with severe negative consequences but also a chance for success) instead of settling for a negative, but tolerable, consequence. This might not be the actual intent of the organization and they would need to be aware of the possibility for this interaction.

(4) Specific conclusions about a policy that allows for a small (but indiscriminate) amount of risk are difficult to make. The research clearly showed that a "70%" chance of a negative outcome for any variable was

intolerable to decision makers following this guidance. Exactly where the acceptable "small" level of risk became unacceptable was not examined in this study but the results of the research suggest that this level may be unique to each decision variable. In this study, for instance, a 30% chance for a negative reliability was too risky for the logisticians. However, a 30% chance of negative cost was treated as only slightly less preferable than certain cost. This suggests that a policy which is vague in stating an acceptable level of risk may be interpreted in different ways for different factors involved in the decision. Another explanation is that a policy which generally draws attention to risk will only affect certain variables. That is, decision makers may only consciously apply the risk policy to selected variables (perhaps, the variables they deem most important).

The implication to logistics organizations is that a risk policy which is stated in vague or uncertain terms may not yield the desired results. Management's attempt to influence risk-related decisions may only be successful in specific situations. The policy will likely not be applied to all decision variables uniformly. Even a vague policy, however, will reduce the level of risk taking compared to no policy at all.

### Recommendations for DoD, Air Force, and Logistics Managers

It is important for managers to realize that risk is present in many of the strategic and operational decisions made by people in their organizations. Naturally, they hope and expect that risk-related decisions are made with the aim of perpetuating organizational goals. However, studies show that, at times, people will respond to risk in a seemingly irrational manner. If, instead, policies which address risk can influence these decisions in a predictable and desired manner, management can have greater assurance that decisions will closely reflect organizational goals. This research clearly showed that such influence can be achieved although not for all situations. The complexity resulting from the interactions between decision variables may mean that certain risk policies will only affect specific decision situations.

It is equally important for managers in DoD and Air Force organizations to be aware of which decisions they or their employees are making currently address risk. Decisions are deemed risky if a decision choice can potentially result in a loss. The loss may be evident in terms of cost, performance, customer service, safety, profit, or a myriad of other variables. Managers should have an explicit understanding of where risk is manifested in their organizational decisions.

Managers should also initiate studies to determine which risk policies will produce a more desirable influence

on the decisions made in their organizations. A systematic analysis of the interactions between a policy and all the other decision variables is needed in order to adequately determine how the policy will influence risk-related decisions.

Finally, managers should structure their risk policies and, hence, establish their risk posture in a manner which perpetuates organizational goals. The policies should be specifically worded to achieve a predictable response from the decision makers. After all, risk-related decisions represent an important and potentially beneficial class of organizational decisions, especially in the field of logistics; the ability to influence these decisions would prove enormously useful to these organizations.

#### Recommendations for Future Research

The scope and format that an experimental design similar to this research can take are nearly limitless. More research efforts are needed to substantiate which management policies will produce a more predictable influence on risk-related logistics decisions.

Naturally, this type of experiment can be attempted using other policies. Policy C, for instance, could be modified to explicitly establish a minimum acceptable level of risk, either in terms of probabilities or degree of negative consequences. In this thesis, for example, the variables were either positive or negative, and all

uncertain data had expected values equal to their counterpart certain data. Use of graduated degrees of positive and negative values would provide useful insights into what risks logisticians are willing to take and into what degrees of risk can be influenced by risk policies.

An entire research effort can establish the level of risk in terms of probabilities it takes for logisticians to change their decisions. For instance, if a 30% chance of a loss is acceptable, what about a 40% chance, or a 50% chance? Further, are these percentages changed by the risk policy of an organization? These ideas can be applied to other logistics variables. The level of acceptable risk may vary widely when comparing customer service, for example, with cost, delivery schedule, or reliability; and the degree to which the level of acceptable risk can be influenced by policies may vary according to each specific variable.

Essentially, this thesis used the concept of opportunity losses to establish the negative outcomes. Logistics decisions often encounter this situation. However, situations may arise where logistics decisions could result in losses in an absolute sense. Not only would the outcome be less appealing than another potential outcome, it would also represent a loss to the organization in absolute terms. Risk propensities and the influence of policy on risk behavior may be significantly different.

Finally, logistics areas other than purchasing decisions should be researched to determine the influence of

risk policies. Purchasing decisions are often laden with restrictive procedures and can revert to political decisions, subjugating the role risk plays on influencing the individual decision maker. Decisions concerning flight-line maintenance or, perhaps, base supply stockage policies may have implications germane to the study of risk influences and the affects of risk policies on decisions made by logistics managers. Other areas, such as life-or-death situations involving risk decisions, should also be explored.



## Appendix A: Section I of the Experiment: Introductions

### INTRODUCTION (Policy A)

In most organizations the decisions to purchase major equipment items, build facilities, or acquire services are made only after evaluating many factors. Ideally, the benefits derived from the product should exceed the expected costs. The decision to choose one vendor over another is often a subjective evaluation of how well each one will actually perform against the criteria considered important. Despite what a vendor proposes, factors such as costs, delivery schedules, product reliability, maintenance requirements, etc. are seldom met exactly. A vendor may overstate or understate his abilities or the product's quality.

Situation. Your unit is evaluating proposals to purchase an advanced data automation and decision support system network. The system would consist of a mini-computer with associated peripherals (terminals, network communications links, software,...). The money to purchase the system represents a portion of your unit's O&M funds. Since the money you spend on the system is money that could otherwise be used elsewhere (such as for TDYs or training courses), you have a vested interest in the total cost. Your unit has budgeted \$100,000 for this purchase, and any

relative savings from the purchase below the budgeted amount provides funds for other uses. Similarly, you have a substantial interest in the performance of the system since you and your subordinates will be among the major users. If it works reliably, your job will be easier and more can be accomplished. If it does not work well, less will be accomplished and it will be several years before another new system can be purchased.

Your supervisor has previously asked a panel of systems analysts to assess proposals from 16 vendors regarding cost factors, performance variables, and suitability to the mission. They found that most items were relatively equal among proposals and satisfactory to the organization. However, the 16 vendors varied in their ability to guarantee performance in the areas of cost and system reliability.

All costs considered are limited to one-time acquisition costs. On some proposals costs could be stated with 100% certainty. They may be higher or lower than the desired \$100,000, but the costs are known. In other proposals, cost is uncertain and could only be stated in probabilistic terms. These probabilities were derived from analytical and subjective assessments of the vendors by the panel of expert analysts.

System reliability was measured in terms of the percentage of time the system was operating ("uptime"). Downtime includes activities such as preventative maintenance

and system modifications as well as downtime that occurs due to hardware and software problems. No system is able to operate 100% of the time. In fact, the industry average for this type of system is 90%. Each additional percent of uptime represents a substantial increase in an organization's productivity. As with costs, some systems' reliabilities could be stated with certainty, while others only in probabilistic terms. For example, the reliability of a system might be assessed as follows:

System Reliability:

10% chance the system will be up 98% of the time  
20% chance the system will be up 93% of the time  
30% chance the system will be up 86% of the time  
40% chance the system will be up 82% of the time

Objective. Your objective is to consider the 16 proposals submitted to your unit, to evaluate each one, and then to rank order the 16 from best to worst.

Guidance. Because this project is so important to your organization, this is a good opportunity for you to impress your supervisor and guarantee a good performance evaluation. Your supervisor asks you to remember that all other logistics considerations are equal and only cost and system reliability vary among proposals. He is adamant that both cost and reliability data be known absolutely before awarding the contract. If these factors are known beforehand with 100% certainty, even though they may be unfavorable, he can immediately plan other courses of action based on those

figures. Your supervisor expects you to consider this guidance when assessing the proposals.

Four example alternatives are included to show the scope of the alternatives which you will evaluate. When reviewing each proposal remember:

1) Cost and system reliability are independent. That is, a low cost does not imply low reliability, nor does high cost necessarily mean reliability will be high.

2) The proposals have been reviewed for accuracy and management considers the data correct. Your assessment should be based on these figures.

3) Only after you have rated each of the 16 proposals, remove them from the notebook and review them again. Assign each a rank (1 being the best, on down to 16 being the worst) and place that rank in the top right hand corner of the page. You may change any rating if you wish to, then place them back in the notebook in your order of preference. The most appealing alternative should be on top, down to the least attractive alternative on the bottom.

## INTRODUCTION (Policy B)

In most organizations the decisions to purchase major equipment items, build facilities, or acquire services are made only after evaluating many factors. Ideally, the benefits derived from the product should exceed the expected costs. The decision to choose one vendor over another is often a subjective evaluation of how well each one will actually perform against the criteria considered important. Despite what a vendor proposes, factors such as costs, delivery schedules, product reliability, maintenance requirements, etc. are seldom met exactly. A vendor may overstate or understate his abilities or the product's quality.

Situation. Your unit is evaluating proposals to purchase an advanced data automation and decision support system network. The system would consist of a mini-computer with associated peripherals (terminals, network communications links, software,...). The money to purchase the system represents a portion of your unit's O&M funds. Since the money you spend on the system is money that could otherwise be used elsewhere (such as for TDYs or training courses), you have a vested interest in the total cost. Your unit has budgeted \$100,000 for this purchase, and any relative savings from the purchase below the budgeted amount provides funds for other uses. Similarly, you have a

substantial interest in the performance of the system since you and your subordinates will be among the major users. If it works reliably, your job will be easier and more can be accomplished. If it does not work well, less will be accomplished and it will be several years before another new system can be purchased.

Your supervisor has previously asked a panel of systems analysts to assess proposals from 16 vendors regarding cost factors, performance variables, and suitability to the mission. They found that most items were relatively equal among proposals and satisfactory to the organization. However, the 16 vendors varied in their ability to guarantee performance in the areas of cost and system reliability.

All costs considered are limited to one-time acquisition costs. On some proposals costs could be stated with 100% certainty. They may be higher or lower than the desired \$100,000, but the costs are known. In other proposals, cost is uncertain and could only be stated in probabilistic terms. These probabilities were derived from analytical and subjective assessments of the vendors by the panel of expert analysts.

System reliability was measured in terms of the percentage of time the system was operating ("uptime"). Downtime includes activities such as preventative maintenance and system modifications as well as downtime that occurs due to hardware and software problems. No system is able to

operate 100% of the time. In fact, the industry average for this type of system is 90%. Each additional percent of uptime represents a substantial increase in an organization's productivity. As with costs, some systems' reliabilities could be stated with certainty, while others only in probabilistic terms. For example, the reliability of a system might be assessed as follows:

System Reliability:

10% chance the system will be up 98% of the time  
20% chance the system will be up 93% of the time  
30% chance the system will be up 86% of the time  
40% chance the system will be up 82% of the time

Objective. Your objective is to consider the 16 proposals submitted to your unit, to evaluate each one, and then to rank order the 16 from best to worst.

Guidance. Because this project is so important to your organization, this is a good opportunity for you to impress your supervisor and guarantee a good performance evaluation. Your supervisor asks you to remember that all other logistics considerations are equal and only cost and system reliability vary among proposals. He reminds you that recent acquisitions have resulted in overbudgeted purchases for equipment that have failed to meet reliability specifications. He has stated that he does not want to purchase any system that will cost greater than \$100,000 or perform at less than a 90% reliability rate. Your supervisor expects you to consider this guidance when

assessing the proposals.

Four example alternatives are included to show the scope of the alternatives which you will evaluate. When reviewing each proposal remember:

1) Cost and system reliability are independent. That is, a low cost does not imply low reliability, nor does high cost necessarily mean reliability will be high.

2) The proposals have been reviewed for accuracy and management considers the data correct. Your assessment should be based on these figures.

3) Only after you have rated each of the 16 proposals, remove them from the notebook and review them again. Assign each a rank (1 being the best, on down to 16 being the worst) and place that rank in the top right hand corner of the page. You may change any rating if you wish to, then place them back in the notebook in your order of preference. The most appealing alternative should be on top, down to the least attractive alternative on the bottom.



## INTRODUCTION [Policy C]

In most organizations the decisions to purchase major equipment items, build facilities, or acquire services are made only after evaluating many factors. Ideally, the benefits derived from the product should exceed the expected costs. The decision to choose one vendor over another is often a subjective evaluation of how well each one will actually perform against the criteria considered important. Despite what a vendor proposes, factors such as costs, delivery schedules, product reliability, maintenance requirements, etc. are seldom met exactly. A vendor may overstate or understate his abilities or the product's quality.

Situation. Your unit is evaluating proposals to purchase an advanced data automation and decision support system network. The system would consist of a mini-computer with associated peripherals (terminals, network communications links, software,...). The money to purchase the system represents a portion of your unit's O&M funds. Since the money you spend on the system is money that could otherwise be used elsewhere (such as for TDYs or training courses), you have a vested interest in the total cost. Your unit has budgeted \$100,000 for this purchase, and any relative savings from the purchase below the budgeted amount provides funds for other uses. Similarly, you have a

substantial interest in the performance of the system since you and your subordinates will be among the major users. If it works reliably, your job will be easier and more can be accomplished. If it does not work well, less will be accomplished and it will be several years before another new system can be purchased.

Your supervisor has previously asked a panel of systems analysts to assess proposals from 16 vendors regarding cost factors, performance variables, and suitability to the mission. They found that most items were relatively equal among proposals and satisfactory to the organization. However, the 16 vendors varied in their ability to guarantee performance in the areas of cost and system reliability.

All costs considered are limited to one-time acquisition costs. On some proposals costs could be stated with 100% certainty. They may be higher or lower than the desired \$100,000, but the costs are known. In other proposals, cost is uncertain and could only be stated in probabilistic terms. These probabilities were derived from analytical and subjective assessments of the vendors by the panel of expert analysts.

System reliability was measured in terms of the percentage of time the system was operating ("uptime"). Downtime includes activities such as preventative maintenance and system modifications as well as downtime that occurs due to hardware and software problems. No system is able to

operate 100% of the time. In fact, the industry average for this type of system is 90%. Each additional percent of uptime represents a substantial increase in an organization's productivity. As with costs, some systems' reliabilities could be stated with certainty, while others only in probabilistic terms. For example, the reliability of a system might be assessed as follows:

System Reliability:

10% chance the system will be up 98% of the time  
20% chance the system will be up 93% of the time  
30% chance the system will be up 86% of the time  
40% chance the system will be up 82% of the time

Objective. Your objective is to consider the 16 proposals submitted to your unit, to evaluate each one, and then to rank order the 16 from best to worst.

Guidance. Because this project is so important to your organization, this is a good opportunity for you to impress your supervisor and guarantee a good performance evaluation. Your supervisor asks you to remember that all other logistics considerations are equal and only cost and system reliability vary among proposals. He is interested in awarding the contract to the most deserving proposal. It is desirable that the system perform with at least a 90% reliability rate and cost less than \$100,000, but your supervisor is willing to accept a proposal with a small chance of not meeting these criteria. He expects you to consider this guidance when assessing the proposals.

Four example alternatives are included to show the scope of the alternatives which you will evaluate. When reviewing each proposal remember:

1) Cost and system reliability are independent. That is, a low cost does not imply low reliability, nor does high cost necessarily mean reliability will be high.

2) The proposals have been reviewed for accuracy and management considers the data correct. Your assessment should be based on these figures.

3) Only after you have rated each of the 16 proposals, remove them from the notebook and review them again. Assign each a rank (1 being the best, on down to 16 being the worst) and place that rank in the top right hand corner of the page. You may change any rating if you wish to, then place them back in the notebook in your order of preference. The most appealing alternative should be on top, down to the least attractive alternative on the bottom.

## INTRODUCTION (Policy D)

In most organizations the decisions to purchase major equipment items, build facilities, or acquire services are made only after evaluating many factors. Ideally, the benefits derived from the product should exceed the expected costs. The decision to choose one vendor over another is often a subjective evaluation of how well each one will actually perform against the criteria considered important. Despite what a vendor proposes, factors such as costs, delivery schedules, product reliability, maintenance requirements, etc. are seldom met exactly. A vendor may overstate or understate his abilities or the product's quality.

Situation. Your unit is evaluating proposals to purchase an advanced data automation and decision support system network. The system would consist of a mini-computer with associated peripherals (terminals, network communications links, software,...). The money to purchase the system represents a portion of your unit's O&M funds. Since the money you spend on the system is money that could otherwise be used elsewhere (such as for TDYs or training courses), you have a vested interest in the total cost. Your unit has budgeted \$100,000 for this purchase, and any relative savings from the purchase below the budgeted amount provides funds for other uses. Similarly, you have a

substantial interest in the performance of the system since you and your subordinates will be among the major users. If it works reliably, your job will be easier and more can be accomplished. If it does not work well, less will be accomplished and it will be several years before another new system can be purchased.

Your supervisor has previously asked a panel of systems analysts to assess proposals from 16 vendors regarding cost factors, performance variables, and suitability to the mission. They found that most items were relatively equal among proposals and satisfactory to the organization. However, the 16 vendors varied in their ability to guarantee performance in the areas of cost and system reliability.

All costs considered are limited to one-time acquisition costs. On some proposals costs could be stated with 100% certainty. They may be higher or lower than the desired \$100,000, but the costs are known. In other proposals, cost is uncertain and could only be stated in probabilistic terms. These probabilities were derived from analytical and subjective assessments of the vendors by the panel of expert analysts.

System reliability was measured in terms of the percentage of time the system was operating ("uptime"). Downtime includes activities such as preventative maintenance and system modifications as well as downtime that occurs due to hardware and software problems. No system is able to

operate 100% of the time. In fact, the industry average for this type of system is 90%. Each additional percent of uptime represents a substantial increase in an organization's productivity. As with costs, some systems' reliabilities could be stated with certainty, while others only in probabilistic terms. For example, the reliability of a system might be assessed as follows:

System Reliability:

10% chance the system will be up 98% of the time  
20% chance the system will be up 93% of the time  
30% chance the system will be up 86% of the time  
40% chance the system will be up 82% of the time

Objective. Your objective is to consider the 16 proposals submitted to your unit, to evaluate each one, and then to rank order the 16 from best to worst.

Guidance. Because this project is so important to your organization, this is a good opportunity for you to impress your supervisor and guarantee a good performance evaluation. Your supervisor asks you to remember that all other logistics considerations are equal and only cost and system reliability vary among proposals.

Four example alternatives are included to show the scope of the alternatives which you will evaluate. When reviewing each proposal remember:

1) Cost and system reliability are independent. That is, a low cost does not imply low reliability, nor does high cost necessarily mean reliability will be high.

2) The proposals have been reviewed for accuracy and management considers the data correct. Your assessment should be based on these figures.

3) Only after you have rated each of the 16 proposals, remove them from the notebook and review them again. Assign each a rank (1 being the best, on down to 16 being the worst) and place that rank in the top right hand corner of the page. You may change any rating if you wish to, then place them back in the notebook in your order of preference. The most appealing alternative should be on top, down to the least attractive alternative on the bottom.



EXAMPLE 1

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 93% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

EXAMPLE 2

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$110,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 98% of the time  
30% chance the system will be up 94% of the time  
20% chance the system will be up 87% of the time  
10% chance the system will be up 82% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

EXAMPLE 3

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 82% of the time  
30% chance the system will be up 86% of the time  
20% chance the system will be up 93% of the time  
10% chance the system will be up 98% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

EXAMPLE 4

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$125,000  
30% chance of costing \$110,000  
20% chance of costing \$ 95,000  
10% chance of costing \$ 80,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 87% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

Appendix B: Section II of the Experiment: The Task

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 93% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
----- -----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

00111110

(# 1-16)

**PROPOSAL ALTERNATIVE:**

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 98% of the time

30% chance the system will be up 94% of the time

20% chance the system will be up 87% of the time

10% chance the system will be up 82% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

10110011

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 87% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

00111101

PROPOSAL ALTERNATIVE:

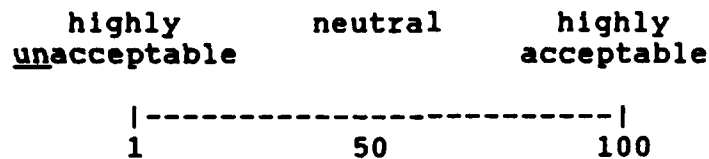
Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$90,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 82% of the time  
30% chance the system will be up 86% of the time  
20% chance the system will be up 93% of the time  
10% chance the system will be up 98% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:



1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

10110001



(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 93% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable

|-----|

1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

00010110

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 98% of the time  
30% chance the system will be up 94% of the time  
20% chance the system will be up 87% of the time  
10% chance the system will be up 82% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

10010011

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 87% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

11010101

(# 1-16)

**PROPOSAL ALTERNATIVE:**

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 82% of the time  
30% chance the system will be up 86% of the time  
20% chance the system will be up 93% of the time  
10% chance the system will be up 98% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                      acceptable  
|-----|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

00011000

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$110,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 93% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>un</u> acceptable	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

10101111

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$110,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 98% of the time  
30% chance the system will be up 94% of the time  
20% chance the system will be up 87% of the time  
10% chance the system will be up 82% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

01101010

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$110,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 87% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

11101101

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

100% chance of costing \$110,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 82% of the time

30% chance the system will be up 86% of the time

20% chance the system will be up 93% of the time

10% chance the system will be up 98% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_

2. What do you expect the system to cost? \_\_\_\_\_

3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

01100000



(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$125,000  
30% chance of costing \$110,000  
20% chance of costing \$ 95,000  
10% chance of costing \$ 80,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 93% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly <u>unacceptable</u>	neutral	highly acceptable
-----		
1	50	100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

11001111

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$125,000  
30% chance of costing \$110,000  
20% chance of costing \$ 95,000  
10% chance of costing \$ 80,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 98% of the time  
30% chance the system will be up 94% of the time  
20% chance the system will be up 87% of the time  
10% chance the system will be up 82% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                      acceptable  
|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

10001010

(# 1-16)

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$125,000  
30% chance of costing \$110,000  
20% chance of costing \$ 95,000  
10% chance of costing \$ 80,000

System reliability is expected to be (Industry average: .90):

100% chance the system will be up 87% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|-----|  
1                      50                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be? \_\_\_\_\_

10001100

PROPOSAL ALTERNATIVE:

Cost of the system is expected to be (Budgeted for \$100,000):

40% chance of costing \$125,000  
30% chance of costing \$110,000  
20% chance of costing \$ 95,000  
10% chance of costing \$ 80,000

System reliability is expected to be (Industry average: .90):

40% chance the system will be up 82% of the time  
30% chance the system will be up 86% of the time  
20% chance the system will be up 93% of the time  
10% chance the system will be up 98% of the time

Please rate this alternative numerically on a scale of  
1 - 100 where:

highly                      neutral                      highly  
unacceptable                                           acceptable  
|-----|-----|  
1                                      50                                      100

1. What is your numerical rating of this alternative? \_\_\_\_\_
2. What do you expect the system to cost? \_\_\_\_\_
3. What do you expect the system's reliability rate to be?  
\_\_\_\_\_

01001000

**Appendix C: Section III of the Experiment:  
The Questionnaire**

**PLEASE ANSWER THE FOLLOWING:**

**USING THE SCALE SHOWN BELOW, PLEASE INDICATE YOUR  
AGREEMENT/DISAGREEMENT WITH THE FOLLOWING:**

	STRONGLY AGREE (SA)	AGREE SLIGHTLY (A)	AGREE SLIGHTLY (AS)	NEUTRAL (N)	DISAGREE SLIGHTLY (DS)	DISAGREE (D)	STRONGLY DISAGREE (SD)
1. The characteristics of the alternatives I evaluated seemed realistic.					SA	A	AS N DS D SD
2. The evaluations I made are comparable to decisions that an organization might make.					SA	A	AS N DS D SD
3. The information included to make an evaluation of the alternatives was adequate.					SA	A	AS N DS D SD
4. Information is seldom available in the form of a probability distribution as was shown with these alternatives.					SA	A	AS N DS D SD
5. I felt as though I should always rate the alternatives based solely upon the cost of the system.					SA	A	AS N DS D SD
6. Generally, reliability is more important than cost.					SA	A	AS N DS D SD
7. Costs are important when making major purchases.					SA	A	AS N DS D SD
8. Product reliability is an important consideration when making a major purchase.					SA	A	AS N DS D SD

ANSWER THE FOLLOWING AS IT APPLIED TO YOUR SITUATION IN THIS EXPERIMENT:

STRONGLY AGREE (SA)	AGREE (A)	AGREE SLIGHTLY (AS)	NEUTRAL (N)	DISAGREE SLIGHTLY (DS)	DISAGREE (D)	STRONGLY DISAGREE (SD)
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9. The numbers presented in the alternatives were too complicated to be useful in making comparisons between alternatives. SA A AS N DS D SD
10. A proposal that has a chance of costing more than \$100,000 would be acceptable to my supervisor. SA A AS N DS D SD
11. A proposal that has a chance of having a reliability rate less than 90% would be acceptable to my supervisor. SA A AS N DS D SD
12. A 40% chance that a system would cost \$75,000 would far and away offset a 10% chance of it costing \$120,000 to my supervisor. SA A AS N DS D SD
13. My supervisor preferred to know the exact cost and reliability of a system. He preferred those alternatives to any in which the performance and cost were less certain. SA A AS N DS D SD
14. In your own words, what was your supervisor's guidance concerning the way you should view any uncertainty regarding cost and reliability as presented in the proposal alternatives?

15. What is the average value of the numbers below?

40% chance of costing \$ 75,000  
30% chance of costing \$ 90,000  
20% chance of costing \$105,000  
10% chance of costing \$120,000      Average value=\_\_\_\_\_

16. What is the expected value of the numbers in question 15?

Expected value = \_\_\_\_\_

17. When compared to a certain cost of a system of \$100,000, which of the following better describes your feeling about an alternative which has the expected outcomes shown in question 15? (Circle only one.)

A. It is an attractive alternative because of the high chance of the lower costs despite the chance of higher costs.

B. It is not as attractive as a system costing \$100,000 for certain because there is a 30% chance that costs will be higher.

18. Which of the following would you prefer?

A. An 80% chance of gaining \$4,000 and a 20% chance of gaining \$0, or

B. A certain gain of \$3,000

19. Which of the following would you prefer?

A. A 25% chance of gaining \$3,000 and a 75% chance of gaining \$0, or

B. A 20% chance of gaining \$4,000 and an 80% chance of gaining \$0

20. Which of the following would you prefer?

A. An 80% chance of losing \$4,000 and a 20% chance of losing \$0 ,or

B. A certain loss of \$3,000

21. Which of the following would you prefer?

A. A 25% chance of losing \$3,000 and a 75% chance of losing \$0, or

B. A 20% chance of losing \$4,000 and an 80% chance of losing \$0

22. Which of the following would you prefer?

A. A 90% chance of gaining \$3,000 and a 10% chance of gaining \$0, or

B. A 45% chance of gaining \$6,000 and a 55% chance of gaining \$0

23. Which of the following would you prefer?

A. A 90% chance of losing \$3,000 and a 10% chance of losing \$0, or

B. A 45% chance of losing \$6,000 and a 55% chance of losing \$0

## PART II BACKGROUND

24. Are you now or have you been in the past two years employed in a logistics management capacity of any kind?

\_\_\_\_\_ (If not, skip to question 28)

25. If so, what is/was your title? \_\_\_\_\_

26. Please circle the general area that you manage(d):

Distribution	Transportation	Maintenance
Warehousing	Supply	Inventory
Materials	Procurement	Other _____



27. How would you assess your organization's emphasis on cost and reliability factors using the following five choices of organization emphasis: (Circle only one)

A. Cost factors receive far more emphasis than reliability factors.

B. Cost factors receive slightly more emphasis than reliability factors.

C. Cost factors and reliability factors receive equal emphasis.

D. Reliability factors receive slightly more emphasis than cost factors.

E. Reliability factors receive far more emphasis than cost factors.

28. Your age \_\_\_\_\_

29. How long have you worked in the field of logistics? \_\_\_\_\_

30. What do you think is the purpose of this research?

31. Please offer any comments you consider relevant.

32. If you are a full time student, what is your academic major?  
\_\_\_\_\_

THANK YOU FOR PARTICIPATING!!

## Appendix D: Questionnaire Responses

Note: This appendix excludes the responses to the open-ended questions.

USING THE SCALE SHOWN BELOW, PLEASE INDICATE YOUR AGREEMENT/DISAGREEMENT WITH THE FOLLOWING:

STRONGLY AGREE (SA)	AGREE (A)	AGREE SLIGHTLY (AS)	NEUTRAL (N)	DISAGREE SLIGHTLY (DS)	DISAGREE (D)	STRONGLY DISAGREE (SD)
---------------------------	--------------	---------------------------	----------------	------------------------------	-----------------	------------------------------

1. The characteristics of the alternatives I evaluated seemed realistic.

SA	A	AS	N	DS	D	SD	AVE
6.4%	43.1%	22.9%	11.8%	8.3%	6.4%	0.9%	2.9

2. The evaluations I made are comparable to decisions that an organization might make.

SA	A	AS	N	DS	D	SD	AVE
8.2%	49.1%	14.5%	13.6%	6.4%	6.4%	1.8%	2.9

3. The information included to make an evaluation of the alternatives was adequate.

SA	A	AS	N	DS	D	SD	AVE
4.6%	19.3%	17.4%	11.0%	22.9%	16.5%	8.3%	4.1

4. Information is seldom available in the form of a probability distribution as was shown with these alternatives.

SA	A	AS	N	DS	D	SD	AVE
12.8%	31.2%	11.9%	21.1%	12.8%	7.3%	1.8%	3.2

5. I felt as though I should always rate the alternatives based solely upon the cost of the system.

SA	A	AS	N	DS	D	SD	AVE
4.6%	3.7%	8.3%	2.8%	15.6%	41.3%	23.9%	5.4

6. Generally, reliability is more important than cost.

SA	A	AS	N	DS	D	SD	AVE
16.5%	17.4%	25.7%	11.9%	15.6%	11.0%	2.8%	3.4

7. Costs are important when making major purchases.

SA	A	AS	N	DS	D	SD	AVE
25.7%	51.4%	8.3%	7.3%	0.9%	4.6%	2.8%	2.3

8. Product reliability is an important consideration when making a major purchase.

SA	A	AS	N	DS	D	SD	AVE
47.7%	45.9%	2.8%	2.8%	0.9%	0.0%	0.0%	2.1

ANSWER THE FOLLOWING AS IT APPLIED TO YOUR SITUATION IN THIS EXPERIMENT:

9. The numbers presented in the alternatives were too complicated to be useful in making comparisons between alternatives.

SA	A	AS	N	DS	D	SD	AVE
1.8%	6.4%	11.0%	17.4%	13.8%	37.6%	11.0%	4.9

10. A proposal that has a chance of costing more than \$100,000 would be acceptable to my supervisor.

SA	A	AS	N	DS	D	SD	AVE
4.6%	22.9%	15.6%	9.2%	13.8%	20.2%	12.8%	4.1

11. A proposal that has a chance of having a reliability rate less than 90% would be acceptable to my supervisor.

SA	A	AS	N	DS	D	SD	AVE
2.8%	13.8%	14.7%	11.0%	17.4%	28.4%	11.9%	4.6

12. A 40% chance that a system would cost \$75,000 would far and away offset a 10% chance of it costing \$120,000 to my supervisor.

SA	A	AS	N	DS	D	SD	AVE
5.5%	25.7%	33.9%	10.1%	13.8%	18.3%	0.9%	3.8

13. My supervisor preferred to know the exact cost and reliability of a system. He preferred those alternatives to any in which performance and cost were less certain.

SA	A	AS	N	DS	D	SD	AVE
22.9%	37.6%	13.8%	8.3%	8.3%	8.3%	0.0%	2.6

15. What is the average value of the numbers below?

40% chance of costing \$ 75,000  
 30% chance of costing \$ 90,000  
 20% chance of costing \$105,000  
 10% chance of costing \$120,000

Average value: \$ 88,400

16. What is the expected value of the numbers in Question 15?

Expected value: \$ 87,350

17. When compared to a certain cost of a system of \$100,000, which of the following better describes your feeling about an alternative which has the expected outcomes shown in Question 15?

A. It is an attractive alternative because of the high chance of the lower costs despite the chance of higher costs.

Respondents answering A: 50.5%

B. It is not as attractive as a system costing \$100,000 for certain because there is a 30% chance that costs will be higher.

Respondents answering B: 49.5%

[Note: The responses to Questions 18-23 are found in Tables 7a and 7b in Chapter IV.]

#### BACKGROUND

24. Are you now or have you been in the past two years employed in a logistics management capacity of any kind?

Yes: 35.6

No: 65.4

26. Please circle the general area that you manage(d):

Warehousing:	2.6%
Transportation:	2.6%
Supply:	15.4%
Procurement:	30.8%
Maintenance:	15.4%
Other:	33.3%

27. How would you assess your organization's emphasis on cost and reliability factors using the following five choices of organization emphasis:

A. Cost factors receive far more emphasis than reliability factors.

B. Cost factors receive slightly more emphasis than reliability factors.

C. Cost factors and reliability factors receive equal emphasis.

D. Reliability factors receive slightly more emphasis than cost factors.

E. Reliability factors receive far more emphasis than cost factors.

A: 25.0%      B: 22.5%      C: 15.0%      D: 22.5%      E: 15.0%

28. Average age:	PCE students:	34.1
	Graduate students:	30.1
	Total:	33.1

29. How long have you worked in the field of logistics?

Average: 5.8 years

[Note: This average is for all respondents that answered this question and did not answer "0 years" (n=54). Many more probably had worked in a logistics field, but the term "logistics" often connotes either a "logistics plans" billet or a job where logistics is specifically annotated (i.e., Deputy Program Manager for Logistics). Since all of the test subjects were either in a logistics related career field or were obtaining a masters degree in logistics management, the responses which stated "0 years" were not counted for this question.]

## Appendix E: Verbal Instructions

- This task is part of a thesis research project.
- Please fill out the first page; your name and social security number are optional.
- The task is presented in 3 sections:
  - Section I is an introduction to a decision making situation. Four examples are included to provide you with the scope of the numbers you will be evaluating in Section II and with the general format of Section II.
  - Section II is the actual task. You are to evaluate 16 alternatives. Please answer each question then remove the alternatives from the notebook, rank order them in order of your preference, then replace them in the notebook. These instructions are repeated throughout the task.
  - Section III is a background questionnaire.
- Please read the introductions carefully and respond to the task as if this was actually your own supervisor and your own organization. A good decision would be beneficial to all concerned.
- Calculators are provided but you do not need to use them if you don't wish to.
- There are no right or wrong answers -- if there were, this research would not be necessary. We are interested in seeing how people respond to these decision situations.
- You may write on any portion of the task; however, please answer all the questions.
- You may refer back to any portion of the task while completing Sections I and II. Once you begin Section III please don't refer back to previous sections.
- While comparing the alternatives in Section II, if you feel you should change any of your previous answers, please feel free to do so.
- The entire task should take 45-50 minutes. If you have any questions please raise your hand and I'll answer them on an individual basis.
- Thank you for your time. Please begin.

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Vita

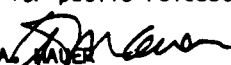
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Research has shown that people respond in varying ways to decisions involving risk. This is of particular interest in the field of logistics. The purpose of this study was to determine whether organizational policies which address risk can produce a significant and predictable influence on risk-related logistics decisions. An experiment was conducted using 117 logistics managers and graduate logistics students. Three policies which specifically addressed the elements of risk were tested for a significant influence on a logistics decision which was based on cost and reliability factors.

Analysis of the responses to the experiment showed that risk significantly affected the logistics decision. Further, the research showed risk-inherent decisions can be purposely influenced by policies which address risk. However, a significant five-way interaction between the policy variable and the other decision variables demonstrated the enormous complexities involved in logistics decision making. No absolute generalizations could be made about any risk policy; the policies produced a significant difference only in certain situations involving certain variables.

A policy which allowed for no uncertainty in the decision outcome (thereby eliminating risk) was most consistently and universally applied. This policy was easily understood, easy to follow, and generally adhered to. A policy which allowed for no negative outcomes (also eliminating risk) was applied only to those variables deemed important by the decision makers, promoting risk-seeking actions in these cases. Finally, a policy which allowed for small risks and focused the decision makers' attention on the concept of risk, but in vague and indiscriminate terms, was also not universally applied to all decision variables. Consequently, organizations may not achieve the desired results from such a policy. Whether such policies are appropriate for logistics organizations would depend on those particular organizations.

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